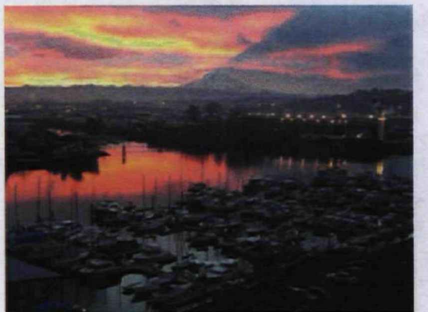
Tacoma

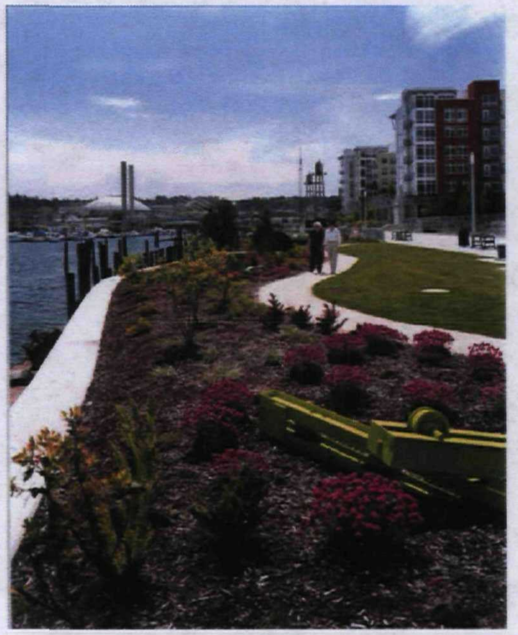
THEA FOSS AND WHEELER-OSGOOD WATERWAYS REMEDIATION PROJECT

YEAR 4 MONITORING

SUBTIDAL CAP HYDROGRAPHIC SURVEY PRELIMINARY FINDINGS MEMORANDUM

JUNE 8, 2010





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PRELIMINARY FINDINGS MEMORANDUM
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INTRODUCTION

This memorandum presents the findings from the Year 4 (2010) Subtidal Cap Hydrographic Survey performed in subtidal slope, grout mat, and channel sand cap areas of the Thea Foss and Wheeler-Osgood Waterways. The hydrographic survey was performed using compatible methodology in accordance with the methods described in Attachment A-1 of the Physical Cap Integrity Operations Manual in Appendix A of the Operations, Maintenance, and Monitoring Plan (OMMP) for the Thea Foss and Wheeler-Osgood Waterways Remediation Project (City of Tacoma, 2006) and in accordance with the USACE Engineering Manual 1110-2-1003, and subsequent manual revisions.

The OMMP requires that multibeam hydrographic surveys be completed in Years 2, 4, 7, and 10 following remedial action construction and be compared to post-construction surveys. Multibeam hydrographic surveys were completed in capped areas in December 2005 and February 2006 upon completion of remedial action construction except for in Remedial Area 1 (RA 1) and RA 3. Post-construction single beam hydrographic surveys were completed in RA 1 and RA 3 in 2003 upon completion of remediation in these areas. The post-construction hydrographic surveys completed in 2003 and 2005/2006 are used as the baseline (Year 0) bathymetric conditions for the capped areas.

The objective for OMMP multibeam hydrographic surveys of subtidal capped areas is to gather data with sufficient density of spot elevations and overlapping beam width to provide complete and comprehensive coverage. Data from the OMMP surveys are compared to previous surveys to assess the integrity of the cap in terms of potential long-term changes in cap thickness within the subtidal slope cap and channel sand cap areas.

The following sections summarize hydrographic survey requirements, the findings of the Year 4 hydrographic survey and the results of the comparative analyses between baseline and Year 4 surveys, and Year 2 and Year 4 surveys. Included with this memorandum are attachments that contain the hydrographic survey contractor's (David Evans Associates Inc. [DEA]) reports describing survey equipment and procedures for the baseline and Year 2 (2008) surveys (Attachment A), and the Year 4 survey (Attachment B). Survey transect lines for the baseline, Year 2, and Year 4 surveys are included as Attachment C.

SUMMARY OF OMMP HYDROGRAPHIC SURVEY REQUIREMENTS

The OMMP specifies that in Years 2, 4, 7, and 10 monitoring be performed to verify cap integrity and performance to ensure containment of the underlying contaminated sediments. The subtidal cap performance monitoring program is designed to detect and evaluate long-term changes in cap thickness to ensure compliance with performance criteria. Hydrographic surveys are to be performed in subtidal slope, grout mat, and channel sand cap areas to evaluate changes (scour / erosion or deposition) in cap thickness as indicated by changes in elevation over time. Subtidal hydrographic survey areas are shown in Figure 1.

As specified in the OMMP, the hydrographic surveys are to be performed using compatible methodology in accordance with the methods as described in USACE Engineering Manual 1110-2-1003 and the methods as described in Attachment A-1 of the Physical Cap Integrity Operations Manual in Appendix A of the OMMP. The intent is for transect locations to follow, to the extent possible, those used in the baseline survey to ensure that the most comparable data are collected.

Hydrographic survey results are compared to previous monitoring surveys to evaluate apparent changes in the cap elevation over time and to identify any potential erosional areas. Consolidation of underlying sediments will be considered in the evaluation of apparent changes in cap thickness, especially during the early years of monitoring. Hydrographic survey data will be evaluated to identify whether there are areas where a contiguous region of the cap exhibits greater than six inches of net erosion relative to previous surveys. One of the performance criteria for the long-term compliance of the sediment cap areas is to maintain a minimum cap thickness of three feet as per the Record of Decision (ROD). A loss of six inches or more of cap thickness will trigger the evaluation of potential response actions. A potential response action may include additional surveys or supplemental field inspections to delineate areas with a loss of more than one foot of cap material and to collect additional information to determine potential causes of the cap material loss, if needed. Included in the OMMP is the Cap Integrity Monitoring Decision Matrix, which includes the evaluation of hydrographic survey data (Figure 2-5 of the OMMP).

The Year 4 multibeam hydrographic survey was performed in accordance with the EPA-approved methods and procedures described in the Physical Cap Integrity Operations Manual (Appendix A of the OMMP). The hydrographic survey contractor report, documenting the equipment and procedures used to conduct the Year 4 survey, is provided in Attachment B.

BASELINE (YEAR 0) HYDROGRAPHIC SURVEYS

The post-construction hydrographic surveys completed in 2003 and 2005/2006 are used as the baseline bathymetric conditions for the cap areas. There are a total of 16 remedial areas that have subtidal slope, grout mat, and/or channel sand caps. An overview of the baseline bathymetric conditions for all 16 remedial areas is shown in Figure 2.

2003 Baseline Surveys – RA 1 and RA 3

The baseline (post-construction) hydrographic surveys for RA 1 and RA 3 were performed in February 2003. These 2003 post-construction surveys were single beam hydrographic surveys performed using Manson Construction Company's (Manson) survey boat and equipment, with survey data processed by Parametrix. Baseline bathymetric conditions are presented in Figure 2, and for individual Remedial Areas in the Year 2 Subtidal Cap Hydrographic Survey Preliminary Findings Memorandum (Year 2 PFM).

The 2003 single beam hydrographic survey was conducted aboard the Manson vessel *Bub*. Soundings were acquired with an Innerspace single frequency fathometer using a frequency of 448 kilo hertz (kHz). The HYPACK MAX hydrographic data collection software was used to integrate a Starlink DNAV212G differential Global Positioning System (GPS) for accurate positioning, the Innerspace fathometer, and a Hazen Tide Gauge for tidal adjustments. 2003 baseline single beam hydrographic surveys were performed in accordance with USACE standards. Specifications for equipment used to perform the baseline 2003 single beam surveys are provided in Attachment A.

2005/2006 Baseline Surveys – RA 5, RA 6, RA 7A, RA 8, RA 9, RA 14, RA 16, RA 17, RA 18, RA 19A, RA 19B, RA 20, RA 21 and RA 22

The baseline multibeam hydrographic surveys for RAs 5, 6, 7A, 8, 9, 14, 16, 17, 18, 19A, 19B, 20, 21 and 22 were performed during two time periods: December 21-22, 2005 and February 12, 2006. Baseline bathymetric conditions for subtidal slope, grout mat, and channel sand cap areas in RAs 5 through 22 are presented in Figure 2.

The 2005/2006 post-construction surveys were multibeam hydrographic surveys performed by David Evans and Associates Inc. (DEA). The hydrographic survey report summarizing the equipment and procedures used for the baseline hydrographic survey, prepared by DEA, is provided in Attachment A.

The 2005/2006 hydrographic survey was conducted aboard DEA's 33-foot vessel *John B Preston*. Soundings were acquired with a Reson SeaBat 8101 multibeam bathymetric sonar using a frequency of 240 kilo hertz (kHz). The system records 101 soundings in a single sonar ping with a 150° swath and with 15° roll bias to starboard. Accurate positioning was determined using a Trimble MS750 RTK Global Positioning System (GPS) rover, located on the vessel with a base station positioned at a control point located on the south side of the Wheeler-Osgood Waterway.

Multibeam data was collected by running lines both parallel and perpendicular to the waterway for the length of the project. In many areas, obstructions from construction activities prevented the vessel from surveying close to the shoreline. Several areas were inaccessible or blocked by large vessels, floats or obstructions. For this survey, the sonar head was mounted with a 15° starboard angle to allow for maximum coverage of side slope areas. This enabled coverage over a range of 90° from nadir (straight down) to starboard and 60° from nadir to port with a recorded depth every 1.5°. The areas where coverage was not obtained in the baseline multibeam survey are identified in Figure 2 as white areas without the hill shade bathymetry located within the RA subtidal hydrographic survey areas.

The accepted angles were opened up along the slopes and to reach under obstructions. The total swath width of full coverage mapping in a single pass varied with the water depth.

To account for vessel heading, heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor was utilized. By utilizing vessel speed over ground and heading data provided by GPS, the POS/MV isolates horizontal accelerations from vessel turns and provides highly accurate motion data. The POS/MV system was also used to record vessel heading (yaw) from which the sonar beam orientation was derived.

YEAR 2 HYDROGRAPHIC SURVEY

The Year 2 multibeam hydrographic survey was conducted by DEA on March 5-6, 2008, with additional quality control checks performed on March 7, 2008. An overview of the Year 2 bathymetric conditions for all 16 RAs is shown in Figure 3. The Year 2 multibeam survey is shown for each subtidal cap area in Figures 4 through 12.

The objective of the Year 2 multibeam survey was to obtain elevation data for subtidal capped areas, defined as the capped areas within RA boundaries extending up the shoreline to a target elevation of 0 feet Mean Lower Low Water (MLLW). Intertidal slope caps placed along the shoreline at elevations above 0 feet MLLW are monitored by low tide slope cap inspections as described in the OMMP. Low tide slope cap inspections are also performed along the shoreline extent of subtidal caps to supplement the hydrographic survey analysis in areas where complete hydrographic coverage is limited due to the presence of structures, marina docks, and other facilities. The hydrographic survey contractor reports summarizing the equipment and procedures used for the Year 2 hydrographic survey are provided in Attachment A.

Consistent with the baseline surveys, soundings were acquired with a Reson SeaBat 8101 multibeam bathymetric sonar using a frequency of 240 kilo hertz (kHz). The system records 101 soundings in a single sonar ping with a 150° swath and with 15° roll bias to starboard. Accurate positioning was determined using a Trimble MS750 RTK Global Positioning System (GPS) rover, located on the vessel with a base station positioned at a control point located on the south side of the Wheeler-Osgood Waterway. The survey was conducted aboard DEA's 33-foot vessel *John B Preston*.

Multibeam data was collected by running lines both parallel and perpendicular to the waterway for the length of the project. Unlike the baseline hydrographic survey, construction activities were not occurring during the Year 2 survey and as a result the vessel was able to survey closer to the shoreline. However, in many areas, the survey vessel had to be "walked" along tight spaces between the shoreline and docks and floats to get the maximum coverage possible. Very few areas were inaccessible. For this survey, the sonar head was mounted with 15° starboard angle to allow for maximum coverage of side slope areas.

To account for vessel heading, heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor was utilized. By utilizing vessel speed over ground and heading data provided by GPS, the POS/MV can isolate horizontal accelerations from vessel turns and provide highly accurate motion data. The POS/MV system was also used to record vessel heading (yaw) from which the sonar beam orientation was derived.

YEAR 4 HYDROGRAPHIC SURVEY

Summary of Year 4 Field Activities

The Year 4 multibeam hydrographic survey was conducted by DEA on March 1-3, 2010, with additional quality control checks performed before and following completion of the survey. The objective of the Year 4 multibeam survey was to obtain elevation data for subtidal capped areas, defined as the capped areas within RA boundaries extending up the shoreline to a target elevation of 0 feet MLLW. Intertidal slope caps placed along the shoreline at elevations above 0 feet MLLW are monitored by low tide slope cap inspections as described in the OMMP. Low tide slope cap inspections are also performed along the shoreline extent of subtidal caps to supplement the hydrographic survey analysis in areas where complete hydrographic coverage is limited due to the presence of structures, marina docks, and other facilities. The hydrographic survey contractor reports summarizing the equipment and procedures used for the Year 4 hydrographic survey are provided in Attachment B.

Consistent with the baseline surveys, soundings were acquired with a Reson SeaBat 8101 multibeam bathymetric sonar using a frequency of 240 kilo hertz (kHz). The system records 101 soundings in a single sonar ping with a 150° swath and with 15° roll bias to starboard. Accurate positioning was determined using a Trimble MS750 RTK Global Positioning System (GPS) rover, located on the vessel with a base station positioned at a control point located on the east side of the Thea Foss Waterway. The control point used in the previous Year 2 survey, control point #2014, was found to be destroyed, and was not available for use in the Year 4 survey. It was determined that the selected control point (control point #2011) was out of position from the published coordinates and elevation, however collection of additional positioning data from three additional control points in the area allowed for valid adjustment to the data during post processing. This is discussed in detail in the DEA methods and procedures memorandum included as Attachment B. The survey was conducted aboard DEA's 33-foot vessel *John B Preston*.

Multibeam data was collected by running lines both parallel and perpendicular to the waterway for the length of the project. Similar to the Year 2 hydrographic survey, construction activities were not occurring during the Year 4 survey and as a result the vessel was able to survey closer to the shoreline. Again, there were some areas where the survey vessel had to be "walked" along tight spaces between the shoreline and docks and floats to get the maximum coverage possible. Additionally, multiple passes were performed with the survey vessel to try to acquire additional data in some areas where access was obstructed by marine structures. Very few areas were inaccessible. For this survey, the sonar head was mounted with 15° starboard angle to allow for maximum coverage of side slope areas.

To account for vessel heading, heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor was utilized. By utilizing vessel speed over ground and heading data provided by GPS, the POS/MV can isolate horizontal accelerations from vessel turns and provide highly accurate motion data. The POS/MV system was also used to record vessel heading (yaw) from which the sonar beam orientation was derived.

The following sections summarize the findings of the Year 4 hydrographic survey, and present the comparison of the baseline and Year 2 surveys to the Year 4 survey.

Year 4 Hydrographic Survey Results

As described above, the Year 4 hydrographic survey was conducted in March 2010. An overview of the Year 4 bathymetric conditions for all 16 RAs is shown in Figure 13. The Year 4 multibeam survey is shown for each subtidal cap area in Figures 14 through 22.

In general, the Year 4 survey was comprehensive, with a greater level of coverage than the Year 2 survey with only a few small scattered areas between approximately 5 and 15 feet wide where complete survey data could not be collected. The areas where the extent of the Year 4 survey coverage was not complete are discussed below with the results for each RA.

Comparability of the Year 4 Survey to Baseline and Year 2 Surveys

The systems and procedures used for the baseline, Year 2, and Year 4 multibeam hydrographic surveys resulted in very good repeatability and survey comparability. The comparability of baseline and Year 2 multibeam surveys to the Year 4 multibeam survey is presented in the DEA equipment and procedures memorandum included in Attachment B. The following systems and procedures that are used to evaluate comparability are discussed in detail in the DEA memorandum:

- **Equipment**: Nearly identical equipment was used in all three surveys. Only the control points varied between the three surveys. The control points that were used for the Year 2 and Year 4 surveys were established during remediation construction. The control points that were used for the baseline survey were destroyed by construction activity.

- **Survey Coverage and Line Orientation**: During the baseline survey, obstructions, generally resulting from construction activities, prevented the vessel from surveying close to the shoreline. However, in the Year 2 and Year 4 surveys, nearly complete coverage of subtidal capped areas was achieved. In general, the trackline orientation of the surveys was controlled by the shape of the waterway and the locations of various marine structures. Therefore, similar transect lines for the surveys were produced. It should be noted, however, that the need for duplicating survey transects is not as significant with multibeam surveys, as it is with single beam surveys. The transect lines generated during the baseline, Year 2, and Year 4 surveys are presented in Attachment C.

- **Quality Control and Checks**: Similar quality control procedures were used in all three surveys, which include control points, sound velocity casts, lead line soundings, and comparisons of RTK tide data to observed NOAA tides, among others. These quality control procedures are also discussed in the survey equipment and procedures memorandums for the baseline, Year 2 and Year 4 multibeam surveys (Attachments A and B).

- **Feature Matching**: Data from a distinct feature in the central portion of the channel was used to further provide quality assurance of the multibeam surveys. The hill shade survey of the remnant bridge footing showed good repeatability between all three surveys.

As consistent equipment, procedures, and quality control were performed for the baseline, Year 2 and Year 4 multibeam hydrographic surveys, the surveys are comparable. As the survey coverage was comprehensive and nearly complete, the Year 4 bathymetric data will provide an excellent surface for future OMMP survey comparisons.

In RAs 1 and 3, single beam surveys were performed during the baseline survey while in Year 2 and Year 4, multibeam surveys were performed. Additionally, in shoreline locations, as described below, post-construction single beam surveys performed by Manson were reviewed and compared to the Year 2 and Year 4 multibeam surveys to evaluate cap surface elevations. Although, in general, the baseline single beam surveys performed in 2003 by Manson and Parametrix in RAs 1 and 3 and the Year 2 and Year 4 multibeam surveys are in relatively good agreement, differences are evident on the shoreline slopes. The Year 2 and Year 4 multibeam surveys tend to be a smoother line than the baseline single beam surveys. In general, the Year 2 and Year 4 surveys were in a tighter alignment than the baseline survey. These are potential artifacts or variability that can result from the comparison of single beam to multibeam surveys. Differences between the single beam and multibeam surveys along shoreline slopes are most likely attributable to transducer beam width. The single beam echo sounder assumes that the first returned echo is located directly below the transducer. However, the cone of the transducer senses the upslope shoreline bottom, but still assumes it is directly beneath it, therefore the recorded depths appear slightly shallower than the true depth from the center of the beam directly below the transducer. The wider the beam, or the further upslope, the greater the potential difference in the true depth. Latency can also contribute to potential slope discrepancy. Latency causes the current depth at which the transducer is located to be logged with the navigation location of the previous reading location, therefore, appearing to be farther down slope; the deeper depths would be recorded in upslope positions making the slope appear deeper than it actually is.

The baseline, Year 2 and Year 4 hydrographic surveys and bathymetric contours are presented relative to a project specific datum, referred to throughout this document as the USACE Port of Tacoma MLLW vertical datum, for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet, converted from NGVD 29 and consistent with the datum used for remedial construction.

COMPARISON OF THE YEAR 4 SURVEY TO BASELINE AND YEAR 2 SURVEY RESULTS

The following sections present the comparison of baseline and Year 2 survey results to the results of the Year 4 hydrographic survey performed in subtidal cap areas. In RAs 5, 6, 7A, 8, 9, 14, 16, 17, 18, 19A, 19B, 20, 21 and 22, multibeam surveys were performed during baseline, Year 2 and Year 4. In RAs 1 and 3, single beam surveys were performed during baseline while multibeam surveys were performed during Year 2 and Year 4.

The comparison of the baseline multibeam bathymetric surface to the Year 4 multibeam bathymetric surface is presented in Figure 23. The bathymetric surfaces of RAs 1 and 3 were not included in the comparison provided in Figure 23 as single beam baseline surveys were performed in these RAs. The Year 2 multibeam bathymetric surface is compared to the Year 4 multibeam bathymetric surface in Figure 24. This figure does include a comparison of the Year 2 and Year 4 multibeam bathymetric surface for RAs 1 and 3 since they were performed in a similar manner.

The gray areas of the waterways in Figures 23 and 24 indicate areas where the change in elevations between the Year 4 survey compared to the baseline survey and the Year 2 survey are within +/- six inches and within the allowable accuracy of the survey equipment. Elevations highlighted in shades of green indicate areas that are shallower (i.e., higher elevations) in Year 4 relative to the baseline elevations surveyed in 2005/2006 or the Year 2 elevations surveyed in 2008. Elevations highlighted in shades of blue indicate areas that are deeper (i.e., lower elevations) in Year 4 than in 2005/2006 or 2008.

In shoreline slope areas that were inaccessible or blocked by large vessels, floats or obstructions, the baseline multibeam survey had to use wider sonar angles along the slopes and to reach under such obstructions, which can result in less accurate readings. In these shoreline slope areas where the baseline survey coverage was limited, there appears to be greater variance between the baseline and the Year 2 and Year 4 cap surface elevations, likely as a result of the wider sonar angles.

As single beam surveys provide a narrow transect of data in comparison to the broad coverage provided by multibeam surveys, the comparison of the baseline survey to the Year 2 and Year 4 surveys for RAs 1 and 3 is performed using cross sections. Four cross sections were prepared at regular intervals within each RA to represent typical conditions in RAs 1 and 3 (Figures 25 through 28). Cross sections were also used for comparison in shoreline slope cap areas where the comparison of baseline to Year 2 and Year 4 hydrographic surveys were difficult due to limited coverage of the baseline multibeam survey. Cross sections comprised of Manson single beam surveys, Year 2 multibeam and Year 4 multibeam survey data were prepared and are discussed in specific RA sections below.

As specified in the OMMP and described above, one of the performance criteria for the long-term compliance of the sediment cap areas is to maintain a minimum cap thickness of three feet as per the ROD. A loss of six inches or more of cap thickness as determined from the cap integrity hydrographic surveys will trigger the evaluation of potential response actions. The potential response actions may include additional surveys or supplemental field inspections to delineate areas with a loss of more than one foot of cap material and to collect additional information to determine potential causes of the cap material loss, if needed.

The results of survey comparisons are presented below for each RA that includes subtidal capped areas. The following sections describe the capped area within each RA, the composition of subtidal cap, extent of coverage of the baseline, Year 2 and Year 4 hydrographic surveys, and results of the survey comparisons.

Remedial Area 1

The subtidal cap area in RA 1 is located on the western side of the channel adjacent to Thea's Park between approximate Station 2+00 and Station 7+00, at the mouth of the channel (Figure 1). The subtidal cap area in RA 1 consists of slope cap comprised of riprap, slope cap filter material, and habitat mix.

The Year 4 multibeam survey provided complete coverage of the capped area within RA 1, similar to the Year 2 survey (Figures 14 and 4, respectively). The baseline (post-construction) survey in RA 1 was conducted using single beam surveys. Therefore, the baseline and Year 4 cap surveys are evaluated by comparing elevations along prepared cross sections located along single beam survey transects. Since both the Year 2 and Year 4 surveys were conducted using multibeam, comparison of the Year 4 survey to the Year 2 survey is shown in Figure 24. Figure 25 shows the cross section or transect locations throughout the capped area of RA 1. Figure 26 presents the comparison between the baseline, Year 2 and Year 4 elevations at each of four cross section locations: A-A', B-B', C-C', and D-D'. The surface elevations for each of the three surveys, at 10-foot intervals along the cross sections, as well as the difference between the baseline and the Year 4 elevations and between the Year 2 and Year 4 elevations are shown on the bottom of each cross section.

The channel capped areas of RA 1 in the baseline, Year 2 and Year 4 surveys (i.e., below approximate elevations -25 to -30 feet MLLW) show consistent elevations, do not indicate any compaction or erosion, and are within six inches of each other and within the allowable accuracy of the survey equipment. However, along the shoreline slope capped areas, the Year 4 survey shows elevations that are lower than the baseline elevations in the cross sections discussed above. The decrease in slope cap elevations from baseline to Year 4 along the RA cross sections ranges from less than six inches to 2.4 feet. Elevations of the Year 4 survey are generally within 0 to 0.2 feet of the Year 2 survey elevations as shown by the cross sections, and the comparison figure (Figure 24). Consistent with the Year 2 surveyed elevations, the Year 4 elevations along the slope and channel do not indicate sloughing, since at the toe of the slope the elevations are relatively consistent. The survey comparison of Year 4 to Year 2 and baseline potentially indicates that some settlement or subsidence occurred between construction and the Year 2, but does not indicate any additional settlement or subsidence of the slope cap materials occurred between Year 2 and Year 4.

Potential artifacts or variability can result from the comparison of single beam to multibeam surveys. Differences between single beam and multibeam surveys along shoreline slopes are most likely attributable to the transducer beam width, but can also include latency and draft issues. The deeper flat channel areas that were surveyed by the single beam surveys as baseline and by multibeam surveys in Year 2 and Year 4 agreed well, which would indicate that there are no vertical datum or draft issues.

No response actions are warranted based on the results of comparison of baseline and Year 4 hydrographic surveys in RA 1. An evaluation of the results indicates that there are no indications of sloughing or erosional forces and that the likely differences in slope elevations are either a potential artifact and variability between comparing the elevations from single beam and multibeam surveys or potential settlement, or subsidence has occurred along the shoreline slope following construction and prior to Year 2. No additional settlement or subsidence of the slope cap materials was observed from Year 2 to Year 4. This area will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 3

The subtidal cap area in RA 3 is located on the eastern side of the channel adjacent to Commencement Bay Marine (formerly Totem Marine) between approximate Station 27+00 and Station 31+00 (Figure 1). The subtidal cap area in RA 3 consists of grout mat or a slope cap comprised of riprap, slope cap filter material, and habitat mix.

The Year 4 multibeam survey provided complete coverage of the capped area within RA 3 (Figure 15). Two areas of limited coverage during the Year 2 survey (Figure 5) were accessible during the Year 4 survey. Similar to RA 1, the baseline survey in RA 3 was conducted using single beam surveys. Therefore, comparison of the Year 4 survey to baseline was conducted by comparing elevations along prepared cross sections. Figure 27 shows the cross section locations throughout the capped area of RA 3. Figure 28 presents the comparison between the baseline, Year 2 and Year 4 elevations at each of four cross section locations: E-E', F-F', G-G', and H-H'. The surface elevations for each of the three surveys at 10-foot intervals along the cross sections, as well as the difference between the baseline and the Year 4 elevations, and between the Year 2 and Year 4 elevations are shown on the bottom of each cross section.

In the harbor areas of RA 3 (i.e., below approximate elevations of -25 feet MLLW), the baseline, Year 2, and Year 4 surveys show consistent elevations, do not indicate any compaction or erosion, and are within six inches of each other. However, along the shoreline slope capped areas the Year 4 survey shows increased variability in the cap surface compared to baseline, with elevations that are both lower and higher than the baseline elevations. The largest difference in elevation in RA 3 indicated in the Year 4 and baseline survey comparison is located in cross section F-F', where the Year 4 slope elevation of +9.0 was surveyed to be 1.9 feet higher than the baseline elevation. The higher Year 4 elevation is relatively consistent with the Year 2 survey, as the Year 2 elevation was 1.5 ft higher than the baseline elevation. Also consistent with the Year 2 survey, the largest decrease in elevation in Year 4 compared to baseline was located in cross section E-E', with a decrease of 1.6 feet. In Year 2 the elevation at this cross section was 1.7 feet lower than baseline. Similar to RA 1, the Year 4 elevations along the slope and channel do not indicate sloughing, since at the toe of the slope the elevations are relatively consistent and within the allowable accuracy of the survey equipment. The Year 4 and Year 2 cross section elevations are consistent with few elevation differences. Comparison of the Year 2 and Year 4 multibeam surveys, shown in Figure 24, indicates scattered, small scale occurrences of both increased and decreased elevation changes between the two surveys, all within the range of 6 to 12 inches. The Year 4 survey indicates that some settlement or subsidence potentially occurred in localized areas along the slope between baseline and Year 2, but does not indicate that additional settlement or subsidence is occurring. Given that the Year 2 and Year 4 survey elevations are both lower and higher at various locations along the slope when compared to the baseline survey, but within 6 inches when compared to each other, the difference between the three surveys is potentially attributable to survey comparison artifacts and/or variability such as transducer beam width or latency.

No response actions are warranted based on the results of comparison of baseline, Year 2 and Year 4 hydrographic surveys in RA 3. An evaluation of the results indicates that there are no significant indications of sloughing or erosional forces and that the likely differences in slope elevations when compared to baseline are likely potential artifacts and variability between comparing the elevations from single beam and multibeam surveys. This area will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 5

The subtidal cap area in RA 5 is located on the eastern side of the channel in the area adjacent to the Petrich Marine Dock between Station 37+10 on the north and Station 39+75 on the south (Figure 1). The subtidal cap area in RA 5 consists of slope cap comprised of riprap and slope cap filter material.

The Year 2 and Year 4 surveys provided complete coverage of the capped area within RA 5 (Figures 6 and 16, respectively). The extent of the baseline multibeam survey along the shoreline slope capped area within RA 5 was limited to approximate elevations of -10 to -12 feet MLLW, rather than 0 feet MLLW.

In general, the Year 4 capped surface elevation is within six inches of the baseline surface elevation and within the allowable accuracy of the survey equipment. There are small, localized, non-contiguous points across RA 5 where the change (increase or decrease) in the cap surface elevation is greater than six inches but less than one foot (Figure 23). The small areas showing a slight decrease in elevation likely represent localized settlement of the cap material. The Year 4 surface elevation is also generally within six inches of the Year 2 surface elevation and within the allowable accuracy of the survey equipment. Along the shoreline in the northern portion of RA 5, there is a localized area where comparison of the Year 2 and Year 4 surveys indicates an increase in the cap elevations of greater than six inches and in a few points greater than one foot (Figure 24). This area of increased elevations was not included in the baseline survey coverage.

As decreases in the Year 4 capped surface in comparison with the baseline and Year 2 capped surfaces are localized and do not represent a contiguous region of elevation change, and are less than one foot, therefore no response actions are warranted in RA 5. This area will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 6

The subtidal cap area in RA 6 is located between approximate Station 48+50 and Station 50+50 adjacent to Outfall 230 (Figure 1). The subtidal cap area in RA 6 consists of a channel sand cap. Slope caps constructed in RA 8 extend into RA 6 but are not considered a component of RA 6 for the purpose of subtidal cap integrity monitoring.

The Year 2 and Year 4 surveys provided complete coverage of the capped area within RA 6 (Figures 7 and 17, respectively). The baseline multibeam survey also provided complete coverage of the capped area within RA 6 (Figure 2).

In general, the Year 4 capped surface is within six inches of both the baseline post-construction capped surface and the Year 4 surface, which is within the allowable accuracy of the survey equipment (Figures 23 and 24). No response actions are warranted for RA 6. This area will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 7A

RA 7A is located in the Foss Harbor Marina (formerly Foss Waterway Marina) harbor area on the west side of the Thea Foss Waterway, within RA 7 (Figure 1). The subtidal cap area in RA 7A consists of a channel sand cap. Slope caps constructed in RA 8 extend into RA 7 but are not considered a component of RA 7 for the purpose of subtidal cap integrity monitoring.

The Year 2 and Year 4 survey provided complete coverage of the capped area within RA 7A (Figures 8 and 18, respectively). The baseline multibeam survey provided nearly complete coverage of the capped area within RA 7A, excluding a small area, approximately 14 feet in size, located adjacent to the shoreward-most marina float.

In general, the Year 4 capped surface is within six inches of both the baseline post-construction capped surface and the Year 2 surface, which is within the allowable accuracy of the survey equipment. There are small, localized, non-contiguous points were the change (increase and decrease) in the cap surface elevation is slightly greater than six inches but less than one foot (Figures 23 and 24). As these points are localized and do not represent a contiguous region of elevation change, and are less than one foot, no response actions are warranted in RA 7A. This area will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 8

The subtidal cap area in RA 8 is located along the western shoreline from Station 52+34 on its southern boundary to Station 34+91 on the north (Figure 1). The subtidal cap area in RA 8 consists of thick slope cap comprised of slope cap filter material, riprap, quarry spalls, and habitat mix.

The Year 4 survey provided nearly complete coverage of the capped area within RA 8. RA 8 coverage for the Year 4 survey is shown in Figures 17 and 18. There is one area at the north end of the RA approximately 25 to 30 feet wide where survey coverage could not be obtained (Figure 18). To the extent possible, this area will be inspected during the upcoming low tide slope cap inspections. In general, however, areas of limited coverage during the Year 2 survey were more accessible during the Year 4 survey. Coverage from the Year 2 survey is shown in Figures 7 and 8.

There are two shoreline areas where the extent of the baseline multibeam survey was limited and did not extend to elevation 0 feet MLLW. These areas are located shoreward of the sea plane float near Outfall 230, and shoreward of the Foss Harbor Marina floats (Figure 2). In these areas, post-construction single beam surveys performed by Manson were reviewed and, where available, shoreline slope survey transects were used for comparison between the baseline, Year 2 and Year 4 surveys to evaluate cap surface elevations. These cross section comparison locations are identified on Figure 23.

Three baseline single beam cross section profiles were available for the area around the sea plane float and Outfall 230. Final post-construction baseline transects were not available in the Foss Harbor Marina area where there is limited baseline multibeam survey coverage. These final baseline cross sections were not available due to the presence of marina floats and structures that prevented survey coverage. However, in this area low tide slope cap inspections are also performed under the OMMP and can be used to supplement the hydrographic survey analysis in areas where complete hydrographic coverage is limited. In shoreline slope areas that were inaccessible or blocked by large vessels, floats or obstructions, the baseline multibeam survey had to use wider sonar angles along the slopes and to reach under such obstructions, which can result in less accurate readings. In these shoreline slope areas where the baseline survey coverage is limited there appears to be greater variance between the baseline and Year 4 cap surface elevations, however comparison of the Year 2 multibeam survey to the Year 4 multibeam survey shows limited areas of variation (Figure 24). The variance observed in the comparison of the Year 4 survey to the baseline survey is potentially due in part to the wider sonar angles used during the baseline survey.

Over the predominant portion of RA 8, the Year 4 capped surface elevation is within six inches of the baseline surface elevation and within the allowable accuracy of the survey equipment. There are localized, non-contiguous points within RA 8 where the increase or decrease in the cap surface elevation is slightly greater than six inches but less than one foot (Figure 23). Additionally, there are two localized areas within the slope cap, located at approximate Station 47+10 and Station 52+25, where comparison of the baseline and Year 4 surveys indicate a decrease in cap elevation of greater than one foot (Figure 23). The two localized areas are approximately 8 to 9 feet in size, and were also observed in the comparison of the Year 2 survey to baseline. This comparison of the Year 2 to Year 4 surveys does not indicate that these locations have decreased since completion of the Year 2 survey. These small areas likely represent localized settlement of the cap material since there is not a corresponding increase in elevation of adjacent materials.

Along the shoreline, under the shoreward marina float located at approximate Station 41+00, there is an area where the Year 2 survey identified a decrease in the cap surface elevation of greater than six inches, with some points indicating a decrease in elevation of greater than one foot (Figure 23). Conditions observed by the Year 4 survey are consistent with the observations from the Year 2 survey (Figure 24), and do not indicate additional settlement or subsidence has occurred in this location since the Year 2 survey in 2008. This area appears to be a localized area of settlement or subsidence as an increase in the surface elevation is not present down slope from the area of decreased elevation.

Several areas have cap surface elevations in the Year 2 and Year 4 surveys that are over one foot higher than baseline surface elevations. The areas with higher surface elevations are in locations where cap maintenance activities were performed. Slope cap maintenance activities were performed at four locations on the slope cap in RA 8 within the Foss Harbor Marina and adjacent to Outfall 230 between June 2007 and January 2008 (Year 1 Slope Cap Maintenance Memorandum). The maintenance activities were performed to remove the exposed portion of two treated wood piles and a portion of a debris mound protruding above the thick slope cap, rebuild the slope at Outfall 230, and reconstruct the slope cap in these maintenance areas. Additional slope cap materials including riprap, quarry spalls, and slope cap filter material were placed up to three feet deep resulting in higher slope elevations in these maintenance areas in RA 8.

Comparison of the Year 2 and Year 4 surveys indicates scour or subsidence may be occurring at Outfall 230 at approximate Station 50+00. An area with cap elevation decreases of 6 inches to greater than 18 inches below the Year 2 cap elevation is visible immediately adjacent to Outfall 230 (Figure 24). This area is approximately 15 to 20 feet wide, and is located near the 0 MLLW mark. Waterward of this area is an approximate 30 foot wide zone of increased cap elevation of 6 to 12 inches when compared to the Year 2 survey. Due to the limited coverage of the baseline survey, this area of decreased cap elevation is not visible in the comparison of the

Year 2 or Year 4 surveys to baseline. The proposed response actions for this area of decreased cap thickness in RA 8 adjacent to Outfall 230 are presented below in the Summary of Preliminary Findings.

There are three cross section comparisons at the sea plane float adjacent to Outfall 230 at Station 49+00, Station 49+50, and Station 50+75 (Figure 23). Figure 29 presents the comparison between the baseline, Year 2 and Year 4 elevations at each of the three cross section locations: I-I', J-J', and K-K'. The surface elevation recorded during each survey at 10-foot intervals along the slope of the cross sections are shown on the bottom of each section. Low tide slope cap inspections will supplement the hydrographic survey analysis in the area adjacent to the sea plane float and surrounding Outfall 230 where baseline survey coverage was slightly limited from approximately -4 to 0 feet MLLW.

The comparisons of the baseline single beam transects with the Year 2 and Year 4 multibeam surveys along this portion of the shoreline of RA 8 show that the Year 4 capped surface is within six inches of the baseline capped surface and within the allowable accuracy of the survey equipment. The greatest difference between baseline and Year 4 cap elevations was 0.3 feet, observed along cross sections I-I' and J-J' (Figure 29). At one location along cross section I-I' the Year 4 cap elevation is 0.3 feet higher than the baseline elevation, while the Year 2 cap elevation was 1 foot higher relative to the baseline elevation. At a location along cross section J-J' the Year 4 cap elevation is 0.3 feet lower than the baseline elevation, while the Year 2 cap elevation was 0.2 feet lower than the baseline elevation (Figure 29).

In summary, the majority of the Year 4 capped surface in RA 8 is within six inches of the baseline capped surface and within the allowable accuracy of the survey equipment. In RA 8 there are small, localized, non-contiguous points where the decrease in the cap surface elevation is slightly greater than six inches and up to one foot. Along the shoreline, under the shoreward marina float located at approximate Station 41+00 there is an area where the decrease in the cap surface elevation is greater than six inches relative to baseline elevations, with some points indicating a decrease in elevation of greater than one foot (Figure 23). This area appears to be a localized area of settlement or subsidence as an increase in the surface elevation is not present down slope from the area of decreased elevation. The elevation of this area remained relatively consistent between Year 2 and Year 4. There is also an area of decreased elevation adjacent to Outfall 230. The proposed response action for this localized area of decreased cap elevation is discussed below in the Summary of Preliminary Findings. As all other areas of decreased elevation in RA 8 are localized and not contiguous, no additional response actions are warranted in RA 8. This area will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 9

The subtidal cap area in RA 9 is located in the mouth of the Wheeler-Osgood Waterway between Wheeler-Osgood Station 5+00 and Station 10+00 (Figure 1). The subtidal cap area in RA 9 consists of a channel sand cap.

The Year 4 survey provided complete coverage of the cap in RA 9 (Figure 19), and was able to access areas that were not reached by the Year 2 survey (Figure 9) due to the location of floats associated with the Marine Floats facility in 2008. The baseline multibeam survey provided complete coverage of the capped area within RA 9.

The majority of the Year 4 capped surface elevation is within six inches of the baseline surface elevation and within the allowable accuracy of the survey equipment, with the exception of a few localized areas along the north and central portions of the RA (Figure 23). At approximate Station 7+30, an approximately 20 foot wide scour area (decreased cap elevation) is visible along the north side of the RA. Directly to the west of the scour area, an area of elevated cap material (higher cap elevation) is visible (Figure 24). The location of this area of decreased cap elevation is adjacent to the location of a marine tug boat that was tied to a Marine Floats dock during the survey. This scour spot is deeper than 12 inches below the baseline cap elevation. To the south of the deeper scour location, an approximately 50 feet wide area of lower cap elevation, which may also be due to scour, is visible on the comparison of the Year 4 survey to baseline in Figure 23. However, there is no adjacent elevated area that would indicate material movement typically associated with scour. This area is at an elevation between 6 and 12 inches below the baseline cap elevation. Proposed response actions for the scour areas or decreased cap thickness in RA 9 are presented below in the Summary of Preliminary Findings.

In addition to the area discussed above, there are a few scattered areas of small, localized, non-contiguous points (less than 10 feet in size) where the decrease in the cap surface elevation is greater than six inches but generally less than one foot (Figure 23). As these points are localized and do not represent a contiguous region of elevation change, and are generally less than one foot, no response actions are warranted for these localized occurrences in RA 9. RA 9 and particularly the scour area will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 14

The subtidal cap area in RA 14 is located on the eastern side of the channel in the area adjacent to the J.M. Martinac Shipbuilding facility (Figure 1). The subtidal cap area in RA 14 consists of slope cap comprised of slope cap filter material, quarry spalls, and habitat mix.

The Year 4 survey provided complete coverage of the northern and western half of the subtidal capped area within RA 14. However, due to the significant number of piling, vessels and boom floats, the extent of the Year 4 multibeam survey in the middle and southeastern (shoreward) portion of the capped area within RA 14 was limited to approximate elevations -2 or -4 feet MLLW in two areas, rather than 0 feet MLLW (Figure 20). The Year 4 survey coverage in the northern portion of the RA was more comprehensive than that of the Year 2 survey, but the Year 2 survey included some coverage of the eastern portion of the RA that was inaccessible during the Year 4 survey (See Figures 10 and 20).

Comparison of the baseline and Year 4 surveys shows that in approximately a third of the capped area within RA 14 the Year 4 elevation is higher (shallower) than the baseline elevation by greater than 12 inches (Figure 23). This was previously observed in the comparison of the Year 2 surface elevation to the baseline surface elevation. Upon review of the dates of the baseline survey and final cap construction it was determined that the slope cap in RA 14 was completed on January 4, 2006, and the baseline survey was performed in RA 14 prior to cap completion on December 22, 2005. Therefore, the baseline survey did not include the final capped surface elevation.

In general, the Year 4 capped surface elevation is within six inches of the Year 2 surface elevation and within the allowable accuracy of the survey equipment. There are a few small, localized, non-contiguous points across RA 14 where the change (increase or decrease) in the cap surface elevation is greater than six inches but less than one foot. In a few of these localized areas, there is a decrease in cap elevation of greater than one foot but less than 18 inches (Figure 24). As these points are localized, do not represent a contiguous region of elevation change, and are for the most part less than one foot, no response actions are warranted in RA 14.

In the slope cap area of RA 14, low tide slope cap inspections are also performed in accordance with the OMMP and can be used to supplement the hydrographic survey analysis in areas where complete hydrographic coverage was limited due to the presence of structures and facilities. Additionally, RA 14 will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 16

The two subtidal cap areas in RA 16 are located on the eastern side of the Thea Foss Waterway within Delin Docks Marina between Station 57+00 and Station 58+85, and Station 52+50 and Station 55+25 (Figure 1). The subtidal cap areas in RA 16 consist of a channel sand cap.

The Year 4 survey provided comprehensive coverage of the capped areas within RA 16, with only a few small (< 5 feet) areas of limited coverage due to docks and vessels in the marina area. These areas are visible as white spots on Figure 21. Figure 11 presents the survey coverage from the Year 2 survey. In the northern capped area within RA 16 the extent of the baseline multibeam survey was limited under the shoreward floats and did not extend to the shoreward edge of the capped area as visible in the comparison of the baseline and Year 4 surveys (Figure 23).

In general, the Year 4 capped surface is within six inches of the baseline post-construction capped surface and within the allowable accuracy of the survey equipment. In both the northern and the southern capped portions of RA 16, the areas beneath the marina floats contain several non-contiguous points where the increase in the cap surface elevation is slightly greater than six inches but less than one foot, and a few instances where increases in cap elevation are greater than one foot. These elevation increases are visible in comparison of the Year 4 survey to baseline (Figure 23) and to the Year 2 survey (Figure 24). These points may represent areas of less accurate survey data due to the location of the marine floats, and access to the area, or may be representative of settlement of shell debris beneath the marine float structures which is a common occurrence in similar environments. This occurrence of elevated surface is observed beneath marina floats in other RAs in the waterway as well. As these points are localized and do not represent a contiguous region of elevation change, no response actions are warranted in RA 16. RA 16 will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 17

The subtidal cap area in RA 17 is located in the central channel of the Thea Foss Waterway, adjacent to the capped areas within RA 16 and RA 19A (Figure 1). The subtidal cap area in RA 17 consists of a channel sand cap from Station 54+85 to Station 58+75.

The Year 2 and Year 4 surveys (Figures 11 and 21, respectively) and the baseline multibeam survey provided complete coverage of the capped area within RA 17.

In the majority of the capped area within RA 17, the Year 4 cap surface elevation is within six inches of the baseline surface elevation and within the allowable accuracy of the survey equipment. There is an area between approximate Station 56+00 and Station 57+00 where the decrease in the Year 4 cap surface elevation is greater than six inches but less than one foot relative to the baseline surface elevation (Figure 23). However this area was previously observed in Year 2 in the comparison of the Year 2 surface elevation to the baseline surface elevation, and appears to be an area of settlement or subsidence of cap material. There is not an adjacent area of increased elevation which would indicate movement of material in the immediate area. A comparison of the Year 4 cap surface to the Year 2 cap surface shows that generally elevations have remained within six inches during the last two years and are within the allowable accuracy of the survey equipment (Figure 24).

The elevations between Year 2 and Year 4 are consistent, with differences of less than 6 inches indicating that additional cap settlement or subsidence has not occurred. This, along with comparing the Year 4 surface and the baseline surface which exhibits a potential change in cap elevation that is less than one foot, no response actions are warranted at this time. However, this area will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 18

The subtidal cap area in RA 18 is located in the central channel of the Thea Foss Waterway, adjacent to the capped area within RA 17 and RA 19A (Figure 1). The subtidal cap area in RA 18 consists of a channel sand cap.

The Year 2 and Year 4 surveys (Figures 11 and 21, respectively), and the baseline multibeam survey provided complete coverage of the capped area within RA 18.

In general, the Year 4 capped surface elevation is within six inches of both the baseline surface elevation and the Year 2 surface elevation, which is within the allowable accuracy of the survey equipment. In comparing the Year 4 surface elevation to the baseline surface elevation, there are several small, localized, non-contiguous points (less than 5 feet in size) where the decrease in the Year 4 cap surface elevation is slightly greater than six inches but less than one foot. Additionally, there is a localized area within the channel sand cap, located at approximate Station 60+75, where comparison of the baseline and Year 4 surveys indicate a decrease in cap elevation of greater than one foot (Figure 23). This localized area is not visible on the comparison of the Year 4 to Year 2 surveys, indicating additional subsidence in this area since Year 2 is not suspected. The localized area is approximately 5 feet in size. The small areas of changed elevation in RA 18 likely represent localized settlement of the cap material since there is not a corresponding increase in elevation of adjacent materials. As these points are localized and do not represent a contiguous region of elevation change, and are generally less than one foot, no response actions are warranted in RA 18. This area will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 19A

The subtidal cap area in RA 19A is located on the southwestern shoreline of the Thea Foss Waterway, adjacent to capped areas of RA 17, RA 18, RA 19B, and RA 21 (Figure 1). The subtidal cap area in RA 19A consists of a combination of a grout mat, channel sand cap, and a slope cap comprised of slope cap filter material, riprap, and habitat mix.

In RA 19A, a six-inch thick grout-filled Uniform Section Mat (USM) was placed on the bottom from approximately four feet into the channel across the channel line and up to an elevation of +3 feet MLLW between approximate Station 68+00 to Station 65+50. The USM was then overlain with a 12-inch layer of channel sand and the slopes covered with a slope cap consisting of filter material, riprap, and habitat mix. In RA 19A between approximate Station 65+50 and

Station 62+25, a channel sand cap was placed in the harbor areas and a cap comprised of slope cap filter material, riprap, and habitat mix was placed on the shoreline.

The Year 4 survey provided nearly complete coverage of the capped areas within RA 19A. However, there were two small areas under marina floats where complete survey coverage could not be obtained (Figures 21 and 22). The first area, located at approximate Station 57+80 to Station 58+20 is approximately 5 feet to 10 feet wide along the shoreline at approximate elevation 0 to -2 MLLW. The second area, located at approximate Station 62+75 is less than 5 feet wide, and located directly beneath a marine float. A greater level of coverage was obtained by the Year 4 survey than by the Year 2 survey (Figures 11 and 12). The baseline multibeam survey had limited coverage in the Dock Street Marina area extending from the shoreward-most floats to 0 feet MLLW along the western boundary of RA 19A (Figure 2). In these areas, where available, post-construction single beam surveys performed by Manson were reviewed and shoreline slope survey transects were used for comparison between the baseline, Year 2 and Year 4 surveys to evaluate cap surface elevations. The cross section comparison locations are identified on Figures 23 and 24.

In shoreline slope areas that were inaccessible or blocked by large vessels, floats or obstructions, the baseline multibeam survey had to use wider sonar angles along the slopes and to reach under such obstructions, which can result in less accurate readings. In the shoreline slope areas where the baseline survey coverage is limited there appears to be greater variance between the baseline and Year 2 and Year 4 cap surface elevations. However, this variance is likely due in part to the wider sonar angles that were necessary to reach under obstructions during the baseline survey.

Two cross section comparisons were performed for the area adjacent to Dock Street Marina (Station 56+00 and Station 57+00) and one cross section comparison was performed for the area further south (Station 62+75). Figure 30 presents the comparison between the baseline, Year 2 and Year 4 elevations at each of the three cross section locations: L-L', M-M', and N-N'. The surface elevations for each of the three surveys, at 10-foot intervals along the cross sections, as well as the difference between the baseline and the Year 4 elevations and between the Year 2 and Year 4 elevations are shown on the bottom of each cross section.

Over the predominant portion of RA 19A, the Year 4 capped surface elevation is within six inches of the baseline and Year 2 surface elevations and within the allowable accuracy of the survey equipment. In general, over the predominant portion of RA 19A there are small, localized, non-contiguous points where the decrease in the cap surface elevation is slightly greater than six inches but less than one foot (Figure 23).

There are three locations in RA 19A with limited baseline survey coverage and decreases in the cap surface elevations of greater than six inches are present. These areas are discussed below and are located at the following approximate stations: 1) Station 54+00; 2) Station 55+00 to Station 60+00; and 3) Station 60+50 to Station 61+80.

A small, localized, non-contiguous area of decreased cap elevation between 6 inches and one foot is present at approximate Station 54+00. This area appears to be an area of settlement or subsidence that occurred between Year 2 and Year 4, as an increase in the surface elevation is not present down slope from the area of decreased elevation.

Along the shoreward portion of the capped area within RA 19A, adjacent to Dock Street Marina between Station 55+00 and Station 60+00, the baseline multibeam survey coverage was limited from approximately -10 to 0 feet MLLW. The comparison of the baseline and Year 4 multibeam surveys in this area showed that there is a decrease in cap elevation that is greater than six inches and at some points, the decrease is greater than one foot. These conditions were similar to those observed in the comparison of the Year 2 survey to the baseline survey. Comparison of the Year 4 and Year 2 surveys indicates changes in cap surface elevation from Year 2 to Year 4 are more limited, localized, non-contiguous areas that include both decreased and increased cap elevations, mainly around station 58+00. Additionally, the comparison of three baseline single-beam transects with the Year 4 multibeam survey show that the Year 4 cap surface elevations range from 0.9 feet higher to 1.1 feet lower than the baseline cap surface elevations (Figure 30). This is a similar range to the variation in elevation between the Year 2 and baseline surveys. This area appears to be an area of settlement or subsidence that occurred between baseline and Year 2, as an increase in the surface elevation is not present down slope from the area of decreased elevation, and elevation changes between Year 2 and Year 4 are more limited.

Along the shoreline, between approximate Station 60+50 and Station 61+80, there is an area where the decrease in the cap surface elevation is greater than six inches but less than one foot between the baseline and Year 4 surveys (Figure 23). This area appears to be a localized area of settlement or subsidence as an increase in the surface elevation is not present down slope from the area of decreased elevation. This area is not visible in the comparison of the Year 2 and Year 4 surveys (Figure 24) indicating conditions in this area have remained consistent since completion of the Year 2 survey.

In the RA 19A subtidal cap area overlying the grout mat and under the marina floats (Station 62+00 to Station 63+00) the baseline survey coverage was limited from approximately -10 to 0 feet MLLW. The comparison of the baseline and Year 4 surveys indicate there are localized points where there are increases and decreases in the cap elevation that are greater than six inches. A comparison of a baseline single beam transect with the Year 4 multibeam survey was conducted at Station 62+75 and showed that the Year 4 capped surface is within six inches of the baseline post-construction capped surface and within the allowable accuracy of the survey equipment (Figure 30).

Consistent with the Year 2 survey, comparison of the Year 4 and baseline surveys indicates an area of increased cap elevation ranging from 6 inches to greater than 1 foot between approximate Station 64+80 to Station 68+00. Similar conditions were observed in the Year 2 cap comparison to baseline, indicating conditions in this area have not changed substantially since completion of the Year 2 survey (Figure 24).

As stated above, over the predominant portion of RA 19A, the Year 4 capped surface is within six inches of the baseline post-construction capped surface and within the allowable accuracy of the survey equipment. There are small, localized, non-contiguous points where there are increases and decreases in the cap surface elevations that are slightly greater than six inches. Along the shoreline, between approximate Station 55+80 and Station 59+80 there are small, localized areas where the decrease in the cap surface elevation is greater than one foot. As these areas are localized, limited in extent, and have not changed substantially since completion of the Year 2 survey, no response actions are warranted for these locations at this time. Along the shoreward portion of two capped areas within RA 19A the baseline multibeam survey coverage was limited and the comparison of the baseline and Year 4 multibeam surveys indicate there are localized points where the cap elevation decreases or increases greater than six inches. However, comparison of post construction single beam surveys indicate that in general the Year 4 capped surface is within six inches of the baseline post-construction capped surface, with localized points with decreases in the cap surface elevation that are slightly greater than one foot. Based on the evaluation of post-construction single beam surveys, no response actions are warranted in the shoreline areas of RA 19A. RA 19A will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 19B

The subtidal cap area in RA 19B is located on the southwestern shoreline of the Thea Foss Waterway, adjacent to the sheetpile wall separating the City and Utilities work areas (approximate Station 70+10) and RA 19A (Figure 1). The subtidal cap area in RA 19B consists of a combination of grout mat, channel sand cap, and a slope cap comprised of slope cap filter material, riprap, and habitat mix. The grout mat as described above in RA 19A, is also present in RA 19B, extending from Station 68+00 to Station 70+10.

The Year 4 survey provided near complete coverage of the capped areas within RA 19B with a few scattered locations of limited data (< 5 feet) beneath floats in the Dock Street Marina. A greater degree of coverage was obtained by the Year 4 survey compared to the Year 2 survey. Baseline survey data in RA 19B is limited along the shoreline from approximate Station 62+30 to Station 63+00 and from approximate Station 64+50 to Station 68+75. Comparison of the Year 2 and Year 4 surveys was possible due to the increased data coverage by both multibeam surveys.

Over the predominant portion of RA 19B, the Year 4 capped surface elevation is within six inches of the baseline surface elevation and within the allowable accuracy of the survey equipment (Figure 23). However, as mentioned above, and relatively consistent with Year 2 surveyed elevations, there are two areas in RA 19B with limited baseline survey coverage, and increases and decreases in the cap surface elevations of greater than six inches appear to be present. These areas are discussed below and are located at the following approximate stations: 1) Station 62+30 to Station 64+00; and 2) Station 64+50 to Station 68+75. A third area with decreases in cap surface elevation of greater than 6 inches but less than 1 foot, and limited areas of decreased elevation greater than one foot are also present between approximate Station 68+80 and Station 70+10, and discussed below.

Along the shoreline, between approximate Station 64+50 to Station 68+75 there is an area where the increase in the cap surface elevation is greater than one foot as discussed in the section above for RA 19A (Figure 23). This area continues into RA 19B at Station 68+00, and appears to be a localized area of deposition. However, a comparison of a baseline single beam transect with the Year 2 and Year 4 multibeam surveys at Station 68+50 shows that the Year 2 and Year 4 capped surfaces are within six inches of the baseline post-construction capped surface and within the allowable accuracy of the survey equipment (Figure 23). In addition, comparison of the Year 2 and Year 4 surveys shows consistent conditions in cap surface elevation between the Year 2 and Year 4 surveys (Figure 24). Figure 31 presents the comparison between the baseline, Year 2 and Year 4 elevations at the cross section location O-O'. The surface elevation at 10-foot intervals along the slope of the cross section, as well as the difference between the baseline and the Year 4 elevations and between the Year 2 and Year 4 elevations are shown on the bottom of the section. The comparison of the baseline single beam transect with the Year 2 and Year 4 multibeam surveys along the shoreline of RA 19B shows that the Year 4 capped surface ranges from 0.3 feet higher to 1.3 feet lower than the baseline surface at one location. This range in elevation is consistent with the range of elevation difference between the Year 2 and baseline surveys. In general, the Year 4 cap surface is within six inches of the baseline post-construction capped surface and within the allowable accuracy of the survey equipment (Figure 31).

Along the shoreline, between approximate Station 68+80 and Station 70+10 there is an area where the decrease in the cap surface elevation is greater than six inches but less than one foot, with a few limited areas (< 5 feet) of cap surface elevation decreases greater than 1 foot (Figure 23) between the Year 4 and baseline surveys. This area appears to be a localized area of settlement or subsidence, or potentially erosion, but not cap sloughing as an increase in the surface elevation is not present down slope from the area of decreased elevation. Comparison of the Year 2 and Year 4 surveys shows a few small scattered areas of decreased cap elevation greater than 6 inches but less than 1 foot. These locations are limited in size, non-contiguous, and are located in the same area of decreased cap elevation observed in comparison of the Year 4 to baseline survey.

In general, the Year 4 capped surface is within six inches of the baseline post-construction capped surface and within the allowable accuracy of the survey equipment. Along the shoreline, between approximate Station 68+80 and Station 70+10 there is an area where the decrease in the cap surface elevation is greater than six inches but less than one foot (Figure 23) with a few, small areas of cap surface elevation greater than one foot. As conditions have remained consistent between the Year 2 and Year 4 surveys, and the areas are limited, non-contiguous, and less than 5 feet in size, no response actions are warranted in the shoreline areas of RA 19B. RA 19B will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 20

The subtidal cap area in RA 20 is located on the eastern side of the channel in the area adjacent to the Johnny's Dock and Foss Landing marinas between Station 70+10 and Station 62+50 (Figure 1). The subtidal cap area in RA 20 consists of a channel sand cap in the harbor area and a slope cap comprised of slope cap filter material, riprap, and habitat mix.

The Year 4 survey provided nearly complete coverage of the capped area within RA 20 (Figure 22). The extent of the Year 4 survey was able to extend up to 0 feet MLLW, providing greater coverage of the northeastern end of the RA than the Year 2 survey as shown in Figure 12. The baseline survey coverage was also limited shoreward of the Johnny's Dock floats between Station 62+20 to Station 63+80 and Station 66+00 to Station 67+00, as well as shoreward of the Foss Landing floats between Station 67+50 to Station 70+00. This limitation in coverage is visible in the comparison of the Year 4 survey to the baseline survey shown in Figure 23.

Over the predominant portion of RA 20, the Year 4 capped surface elevation is within six inches of the baseline and Year 2 surface elevations and within the allowable accuracy of the survey equipment. In general, over the predominant portion of RA 20 there are few, small, localized, non-contiguous points where the decrease in the cap surface elevation from baseline and Year 2 to Year 4 is slightly greater than six inches but less than one foot (Figure 23). There is a localized area within the channel sand cap, located at approximate Station 69+80, where comparison of the Year 2 and Year 4 surveys indicate a decrease in cap elevation of greater than one foot (Figure 24), however when the Year 4 survey is compared to the baseline survey, this area is shown as an area of increased elevation from baseline. This potentially indicates sediment deposition may have occurred between baseline and Year 2 which then settled or eroded between Year 2 and Year 4. The localized area is less than 10 feet in size.

In areas of limited baseline survey coverage, post-construction single beam surveys performed by Manson were reviewed and shoreline slope survey transects were used for comparison between the baseline, Year 2 and Year 4 surveys to evaluate cap surface elevations. The cross section comparison locations are identified on Figures 23 and 24. Two cross section comparisons were performed for the areas adjacent to the Johnny's Dock floats at Station 66+75 and Foss Landing floats at Station 68+50.

In the slope cap areas of RA 20 low tide slope cap inspections are also performed and can be used to supplement the hydrographic survey analysis in areas where hydrographic coverage is limited due to the presence of structures, marina docks, and facilities such as in Johnny's Dock floats between Station 62+20 to Station 63+80 and Foss Landing floats between Station 67+50 to Station 70+00.

Figure 31 presents the comparison between the baseline, Year 2 and Year 4 elevations at the cross section locations: P-P' and Q-Q'. The surface elevations at 10-foot intervals along the slope of the cross sections, and the difference in elevation between the baseline and the Year 4 elevations and between the Year 2 and Year 4 elevations are shown on the bottom of each section. The comparisons of the baseline single beam survey with the Year 2 and Year 4 multibeam surveys along the shoreline of RA 20 show that the Year 4 capped surface in some locations ranges from 0.2 feet to 1.1 feet lower than the baseline surface, and up to 0.5 feet higher than the baseline surface (Figure 29). This is the same range of variation between the Year 2 and baseline survey presented in the 2008 Preliminary Findings Memorandum, indicating that elevations remained relatively consistent between Year 2 and Year 4.

In general, the Year 4 capped surface elevation in RA 20 is within six inches of the baseline surface elevation and within the allowable accuracy of the survey equipment. There are small, localized, non-contiguous points where the decrease in the cap surface elevation is slightly greater than six inches but less than one foot (Figure 23). As these points are localized, do not represent a contiguous region of elevation change, and are less than one foot, no response actions are warranted in RA 20. RA 20 will be further evaluated in the Year 7 hydrographic survey analysis.

Remedial Area 21

The subtidal cap area in RA 21 is located in the central channel of the Thea Foss Waterway, adjacent to the capped areas within RA 18, RA 19A, and RA 20 (Figure 1). The subtidal cap area in RA 20 consists of a channel sand cap.

The Year 2 and Year 4 surveys (Figures 12 and 22, respectively), and the baseline multibeam survey provided complete coverage of the capped area within RA 21.

The Year 4 capped surface elevation is within six inches of both the baseline surface elevation and the Year 2 surface elevation, which is within the allowable accuracy of the survey equipment (Figures 23 and 24). No response actions are warranted for RA 21.

Remedial Area 22

The subtidal cap area in RA 22 is located in the channel, at the southern end of the Thea Foss Waterway, adjacent to the capped areas within RA 19B, RA 20 and RA 21 (Figure 1). The subtidal cap area in RA 22 consists of a channel sand cap and a rock buttress to support the cantilevered portion of a submerged sheetpile wall installed by the Utilities at the southern end of the RA.

The Year 2 and Year 4 surveys (Figures 12 and 22, respectively), and the baseline multibeam survey provided complete coverage of the capped area within RA 22.

The Year 4 capped surface elevation for the channel sand cap area is generally within six inches of both the baseline surface elevation and the Year 2 surface elevation, which is within the allowable accuracy of the survey equipment (Figures 23 and 24). Therefore, no response actions are warranted. The eastern portion of the rock buttress adjacent to the sheetpile wall indicates a decrease in elevation of greater than six inches and in places greater than one foot but less than 18 inches when comparing the Year 4 surface elevation to the baseline surface elevation (Figure 23). In this same location, a comparison of the Year 4 surface elevation to the Year 2 surface elevation shows a decrease in elevation of greater than six inches, but generally less than one foot (Figure 24). As the rock buttress is up to 10 feet high in this area, a potential decrease in elevation that is less than one foot does not warrant evaluation of response actions. However, the rock buttress area, as well as the channel cap in RA 22, will be further evaluated in the Year 7 hydrographic survey analysis.

SUMMARY OF PRELIMINARY FINDINGS

The following summarizes the preliminary findings from the Year 4 hydrographic survey and comparison of the Year 4 survey to the baseline and Year 2 surveys:

- Nearly complete coverage of the subtidal slope, grout mat, and channel sand cap areas was achieved in the Year 4 hydrographic survey.
- The Year 4 hydrographic survey was performed using equipment and procedures comparable to the baseline and Year 2 multibeam hydrographic surveys.
- Single beam baseline transect lines were used, where available, in shoreline areas of limited baseline multibeam survey coverage to aid in evaluating cap surface elevations.
- Low tide slope cap inspections can be used to supplement the hydrographic survey analysis in shoreline slope cap areas where baseline hydrographic survey coverage is limited due to the presence of structures, marina docks and facilities.
- In shoreline slope areas that were inaccessible or blocked by large vessels, floats or obstructions, the baseline multibeam survey had to use wider sonar angles along the slopes and to reach under such obstructions, which can result in less accurate readings. Variances identified in shoreline slope areas of limited baseline survey coverage are potentially due in part to the wider sonar angles that were necessary to reach under obstructions during the baseline survey.
- In general, the Year 4 cap surface elevations are within six inches of the baseline surface elevation and within the allowable accuracy of the survey equipment.
- A comparison of the Year 2 to the Year 4 survey shows that the elevations in most areas have remained fairly consistent during the past two years.

- There are limited locations where the decrease in the cap surface elevation from baseline to Year 4 is greater than six inches but less than one foot. These locations are generally small, localized, and non-contiguous.

Proposed Response Actions

There are two areas identified by the Year 4 survey with proposed response actions. These areas, as discussed in the previous section show conditions that elicit the proposed response actions described below that include development and application of additional operational best management practices (BMPs), additional cap performance monitoring, and data evaluation prior to the next survey conducted in Year 7 (2013). The proposed response actions for RA 8 and RA 9 include the following:

- **RA 8:** The area immediately adjacent to Outfall 230 in RA 8 shows a decrease in cap elevation of greater than 18 inches. This area is immediately adjacent to a downgradient area of increased cap elevation of greater than 1 foot. This decrease in elevation is not visible on the comparison of the Year 4 survey to baseline due to limitations in the baseline survey coverage. The decrease in cap elevation from Year 2 to Year 4 is visible in Figure 24.
-

  Due to a decrease in cap surface elevation identified in the baseline survey, slope cap maintenance work at Outfall 230 was conducted in January 2008. In this maintenance area, 18 inches of slope cap filter material was placed over the area beneath the outfall and on the south side of the outfall. Beneath the outfall, the slope cap filter material was then covered with an 18-inch thick layer of light rip rap. On the south side of the outfall, the slope cap filter material was covered with an 18-inch thick layer of quarry spalls. Habitat mix was then placed over the light rip rap and quarry spalls in the maintenance areas.

  The results of the Year 4 survey indicate a reoccurrence of the decrease in cap elevation from settlement and/or loss of cap material due to the steep slope beneath the outfall and drainage flows that have occurred. As a result, the following response actions are proposed for this location to investigate cap conditions:

  - Low tide cap inspections will be conducted in 2010, and will allow some visual observation of cap condition, erosion, and potential scour at this location. Results of the slope cap inspection in this area will be described in the Slope Cap Inspection PFM.
  - As part of the slope cap performance monitoring, a three point composite sample is taken from the southern portion of RA 8, with one of the three sampling points located near the outfall. The discrete slope cap sample that is collected adjacent to the area of decreased cap thickness will be archived. If the RA 8 slope cap composite sample SC-08B has any SQO exceedences, the discrete slope cap sample from this area will be analyzed for those chemicals that exceeded the SQOs. The location of the slope cap discrete sample proposed for archival and potential analyses is shown in Figure 32. Results of the slope cap performance monitoring in this area will be described in the Sediment and Cap Performance Monitoring PFM.

The results of these inspections and potential additional chemical testing will be used to determine if additional actions may be required to repair the cap in this area, and will be discussed with EPA.

- **RA 9**: In RA 9 at approximate Station 7+30, an area of decreased cap elevation greater than 18 inches is visible along the northern side of the waterway. The depression is approximately 20 feet wide. An associated area of elevated cap is present to the west of the depression. This area is located immediately adjacent to a marine float, where a tug boat was moored at the time of the Year 4 survey, and operations at the Marine Floats facility may be impacting the cap in this area. Proposed response actions in this area include the following:
  - Collection of an additional sediment performance monitoring sample in RA 9 at the deepest point of the cap scour depression as part of the Year 4 performance monitoring event. The depression point is located approximately 140 feet to west of the existing RA 9 cap performance monitoring location CC-18. The location of the depression, the proposed additional cap performance monitoring location, and CC-18 are shown in Figure 33. The additional cap performance sample collected from within the cap depression will be analyzed for all COCs and the results will be used to evaluate whether the decreased cap thickness is impacting the chemical containment effectiveness of the cap in this location. Results of the additional cap performance monitoring sample in this area will be described in the Sediment and Cap Performance Monitoring PFM.
  - Coordination with Marine Floats in the development and application of BMPs for their overwater operations in RA 9 to protect the cap from tug scour. The original remedy design for RA 9 was dredging to a clean surface and backfilling to fill the depression. Therefore, scour modeling was not conducted, nor were BMPs developed for the Marine Floats operations for cap protection. However, detected chemical concentrations in the post-dredge samples exceeded the SQOs (PAHs and one pesticide) and as a result, the sand backfilling placed in RA 9 was ultimately considered a channel sand cap. The City will notify EPA of the BMPs developed with the Marine Floats facility. The additional BMPs will also be presented in the Year 4 Annual Monitoring Report.

  In addition, an area of limited, decreased cap elevation greater than 6 inches and less than 12 inches was identified from approximate Station 7+50 to Station 7+80, and spans the width of the waterway. This area is not visible in the comparison of Year 4 to Year 2 (Figures 24 and 32), which may indicate this decrease in cap elevation resulted from initial settlement, and may not be an ongoing concern. Since this area is limited in size, and is less than 1 foot below the baseline elevation, no response action is required for this area. However, if changes in cap elevation are due to facility operations, BMPs developed for the Marine Floats are likely to benefit this area.

Areas to Further Evaluate in the Year 7 Hydrographic Survey Analyses

Although all RAs will be further evaluated for cap integrity during the Year 7 evaluation planned for 2013, additional focus will be placed on two types of areas in the Year 7 hydrographic survey analysis to identify whether changes in the surface elevation are occurring. These areas include: 1) those that exhibit decreases in the cap surface elevation from baseline to Year 4 that are greater than six inches but less than one foot; and 2) those that exhibit decreases in the cap surface elevation from baseline to Year 4 that are greater than one foot but are small, localized, and non-contiguous. These two types of areas are further described in the following sections.

Areas with Greater Than Six Inches and Less Than One Foot Decreases in Cap Surface Elevation

There are five localized yet continuous areas in three RAs where the decrease in the cap surface elevation from baseline to Year 4 is greater than six inches but less than one foot. These areas are located in RA 17, RA 19A, and RA 19B and are summarized below:

- **RA 17**: Between approximate Station 56+00 and Station 57+00 there is an area where the decrease in the cap surface elevation is greater than six inches but less than one foot (Figure 23). The area appears to be an area of initial settlement or subsidence of cap material post-construction, as it did not vary in elevation between the Year 2 and Year 4 surveys.

- **RA 19A**: There are three areas or locations in RA 19A that showed decreases in the cap surface elevations of greater than six inches in the Year 4 to baseline comparison (see Figure 23). These areas are discussed below and are located at the following approximate stations: 1) Station 55+00 to Station 60+00; 2) Station 60+50 to Station 61+80; and 3) Station 54+00. Areas 1 and 2 are adjacent to or underlying shoreward Dock Street Marina floats, and are areas of limited baseline multibeam survey coverage. Area 2, located between Station 60+50 and Station 61+80, is located at approximately 0 feet MLLW. In all three of these areas, the decrease in the cap surface elevation is greater than six inches but less than one foot. Throughout these areas, small, discontinuous zones are present with a decrease in cap elevation greater than one foot. These areas appear to be localized areas of settlement or subsidence as an increase in the surface elevation is not present down slope from the areas of decreased elevation. Cap surface elevation variance between baseline and Year 4 along the marina slope cap areas may also be related to decreased baseline survey accuracy related to the use of wider sonar angles that were necessary to reach under obstructions during the baseline survey. For the most part, the area did not vary in elevation between the Year 2 and Year 4 surveys.

- **RA 19B**: Along the shoreline, between approximate Station 68+80 and Station 70+10 there is an area where the decrease in the cap surface elevation is greater than six inches but less than one foot (Figure 23). This area appears to be a localized area of settlement or subsidence as an increase in the surface elevation is not present down slope from the area of decreased elevation. For the most part, the area did not vary in elevation between the Year 2 and Year 4 surveys.

Given that the decrease in cap surface elevation in these areas is less than one foot and does not appear to be progressing as indicated by the Year 4 to Year 2 survey comparison, no response actions are warranted to address the conditions discussed above in RA 17, RA 19A and RA 19B at this time. These areas will be further evaluated in the Year 7 hydrographic survey analysis.

Areas with Greater Than One Foot Decrease in Cap Surface Elevation

There are three RAs with areas where a decrease in the cap surface elevation from baseline to Year 4 is greater than one foot; however the areas are generally small, localized, and non-contiguous. These locations are summarized below:

- **RA 1**: Along the shoreline slope cap, the decrease in slope cap elevations range from less than six inches to 2.4 feet as shown in the cross sections in Figure 26. The Year 4 elevations along the slope and channel do not indicate sloughing, as at the toe of the slope the elevations are relatively consistent. The Year 4 survey potentially indicates that some settlement or subsidence has occurred along the shoreline slope; however conditions observed in the Year 4 survey are similar to the conditions observed in the Year 2 survey indicating that there does not appear to be an ongoing issue. Additionally, the difference between the Year 4 and baseline surveys is potentially attributable to survey comparison artifacts and/or variability associated with comparing single beam and multibeam surveys, such as transducer beam width or latency.

- **RA 3**: Along the shoreline slope capped areas the Year 4 survey shows increased variability in the change in surface elevations. Year 4 cap surface elevations are both lower and higher in areas than the baseline elevations. The decrease in slope cap elevations range from less than six inches to 1.9 feet (Figure 28). The Year 4 elevations along the slope and channel do not indicate sloughing, since elevations are relatively consistent at the toe of the slope. The Year 4 survey indicates that some settlement or subsidence has potentially occurred in localized areas along the slope. However, given that the Year 4 surveyed elevations are both lower and higher in areas along the slope, and the elevations observed during the Year 2 and Year 4 surveys are consistent, the difference between the Year 4 and baseline surveys is likely attributable to survey comparison artifacts and/or variability associated with comparing single beam and multibeam surveys, such as transducer beam width or latency.

- **RA 8**: There are two small localized areas within the slope cap where the survey comparisons indicate a decrease in cap elevation of greater than one foot (Figure 23). The two localized areas are approximately 8 to 9 feet in size, and are consistent with observations from the Year 2 survey. Additionally, along the shoreline, under the shoreward marine float located at approximate Station 41+00 there is an area where the decrease in the cap surface elevation is greater than six inches, with some points indicating a decrease in elevation of greater than one foot (Figure 23). This observation is also consistent with the Year 2 survey observations. This area appears to be a localized area of settlement or subsidence as an increase in the surface elevation is not present down slope from the area of decreased elevation. Cap surface elevation variance between baseline and Year 4 along the marina slope cap areas may also be related to decreased baseline survey accuracy related to the use of wider sonar angles that were necessary to reach under obstructions during the baseline survey.

These areas with small, localized, and non-contiguous points showing a decrease in the cap surface elevation from baseline to Year 4 are potentially attributable to artifacts of the baseline single beam surveys compared to the multibeam surveys. In the case of RAs 1 and 3, comparison of the Year 2 and Year 4 surveys indicates conditions are stable, and do not indicate that ongoing slope compaction or subsidence is occurring. As these points are localized and do not represent a contiguous region of elevation change, and are potentially attributable to artifacts of the baseline single beam surveys compared to the multibeam surveys, no response actions are warranted at this time. These areas will be further evaluated in the Year 7 hydrographic survey analysis.

FIGURES

ATTACHMENTS

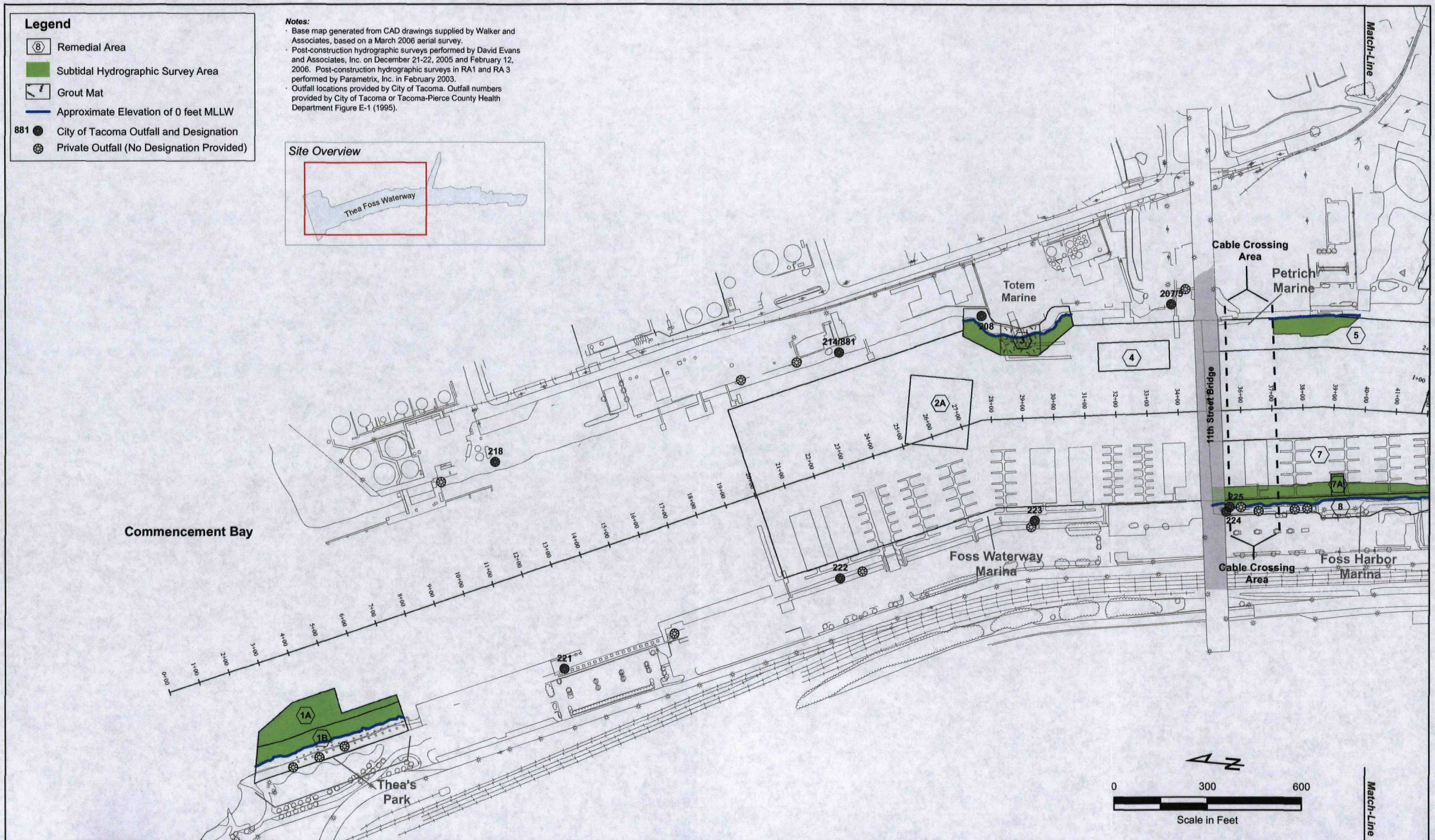

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Figure 1 (Page 1 of 2)
Subtidal Hydrographic Survey Areas

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 1 (Subtidal Hydrographic Survey Areas (1of2)).mxd
Date: 4/5/2010

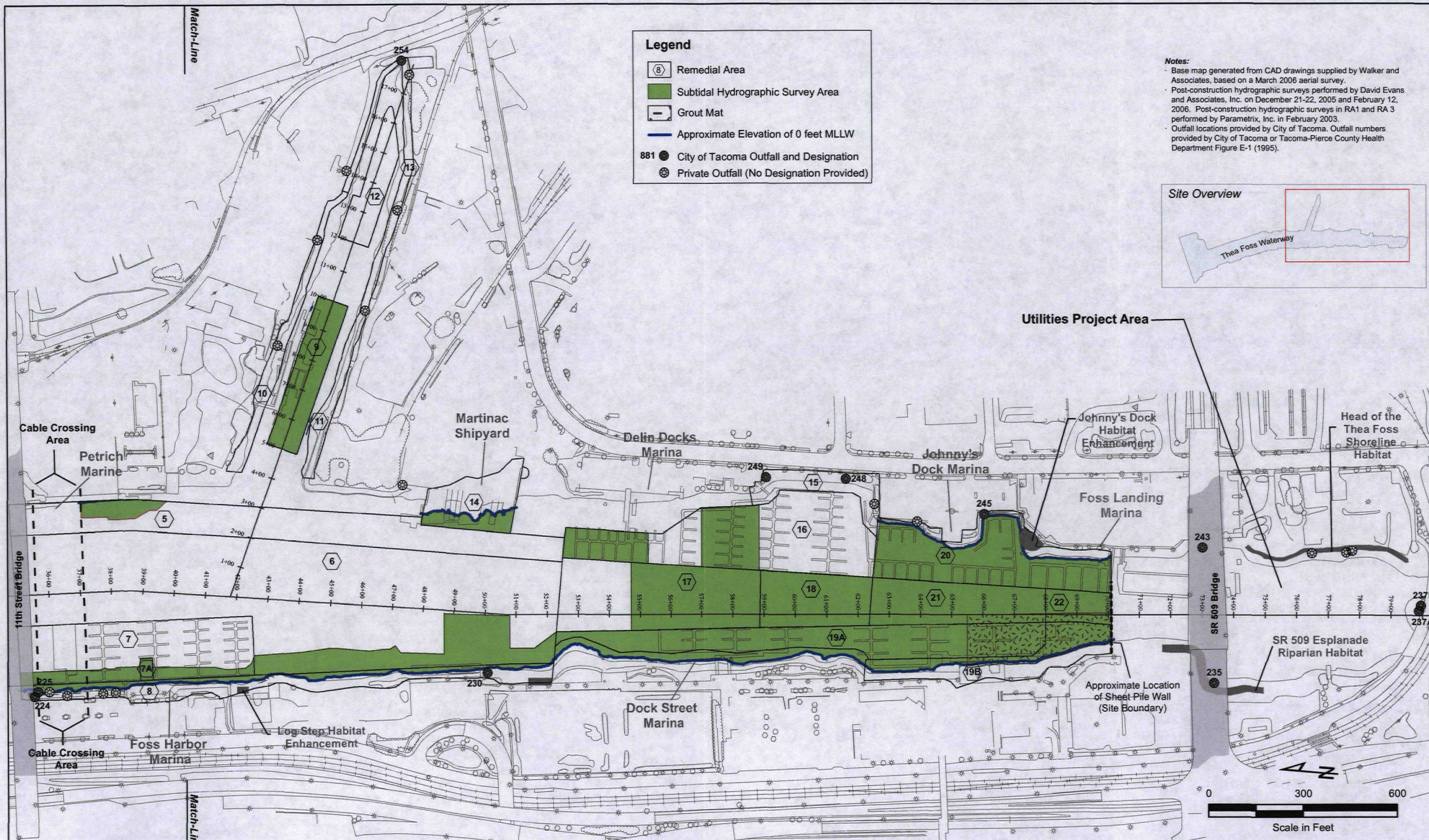

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Figure 1 (Page 2 of 2)
Subtidal Hydrographic Survey Areas

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Date: 5/10/2010

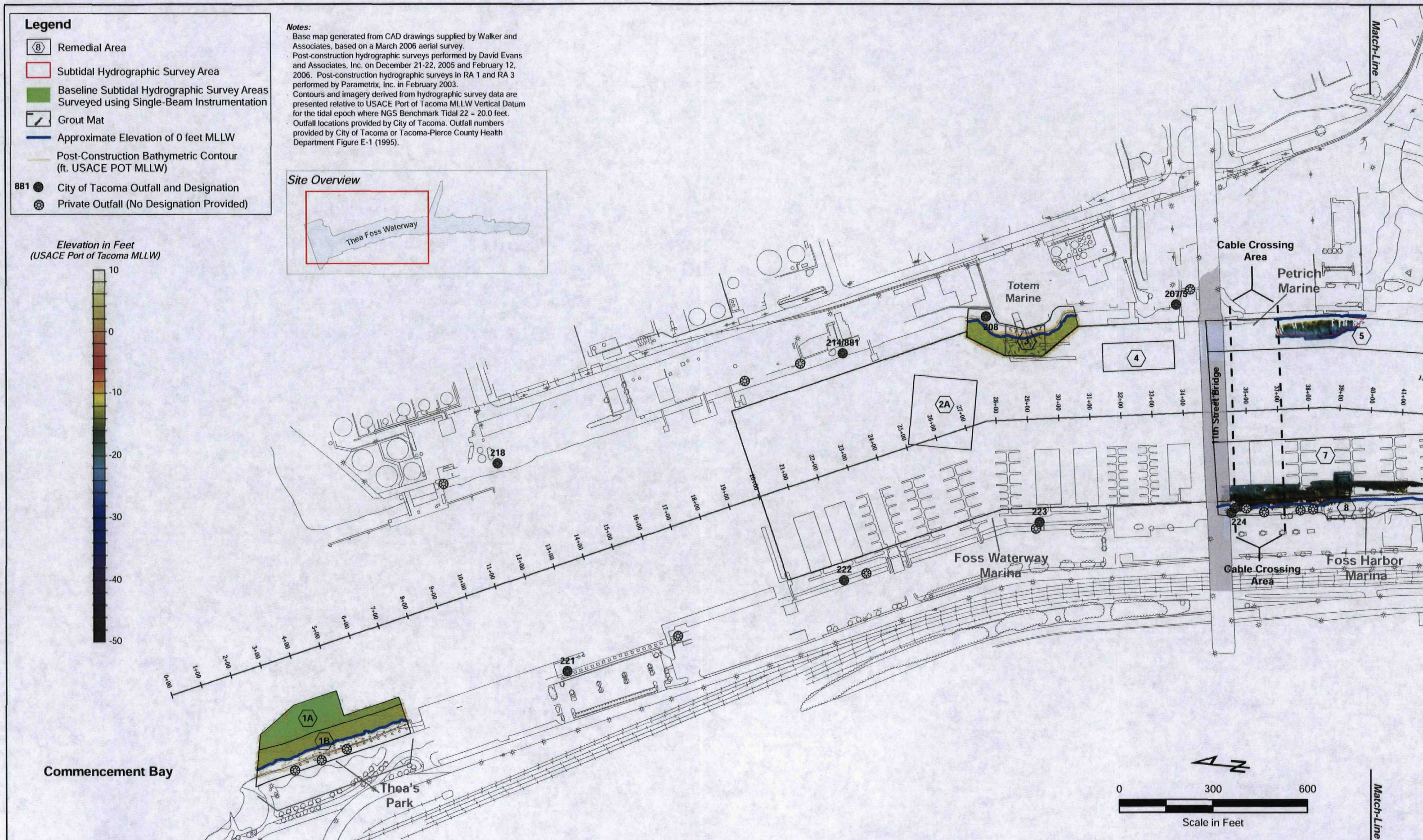

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Figure 2 (Page 1 of 2)
Overview of Baseline Bathymetric Conditions

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 2 (Overview of Baseline Bathymetric Conditions (1of2)).mxd
Date: 4/26/2010

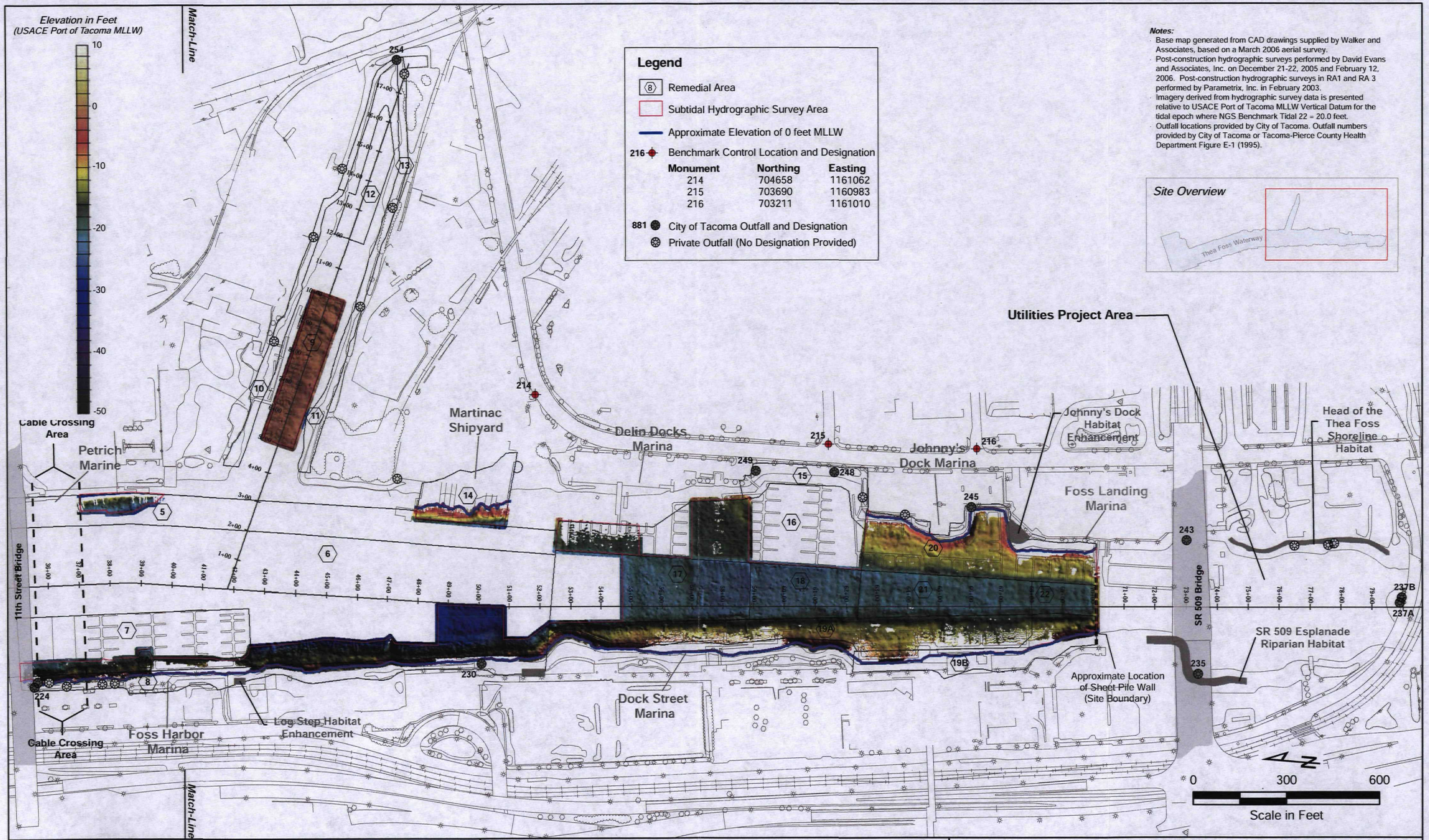

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**Figure 2 (Page 2 of 2)
Overview of Baseline Bathymetric Conditions**

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Date: 4/19/2010

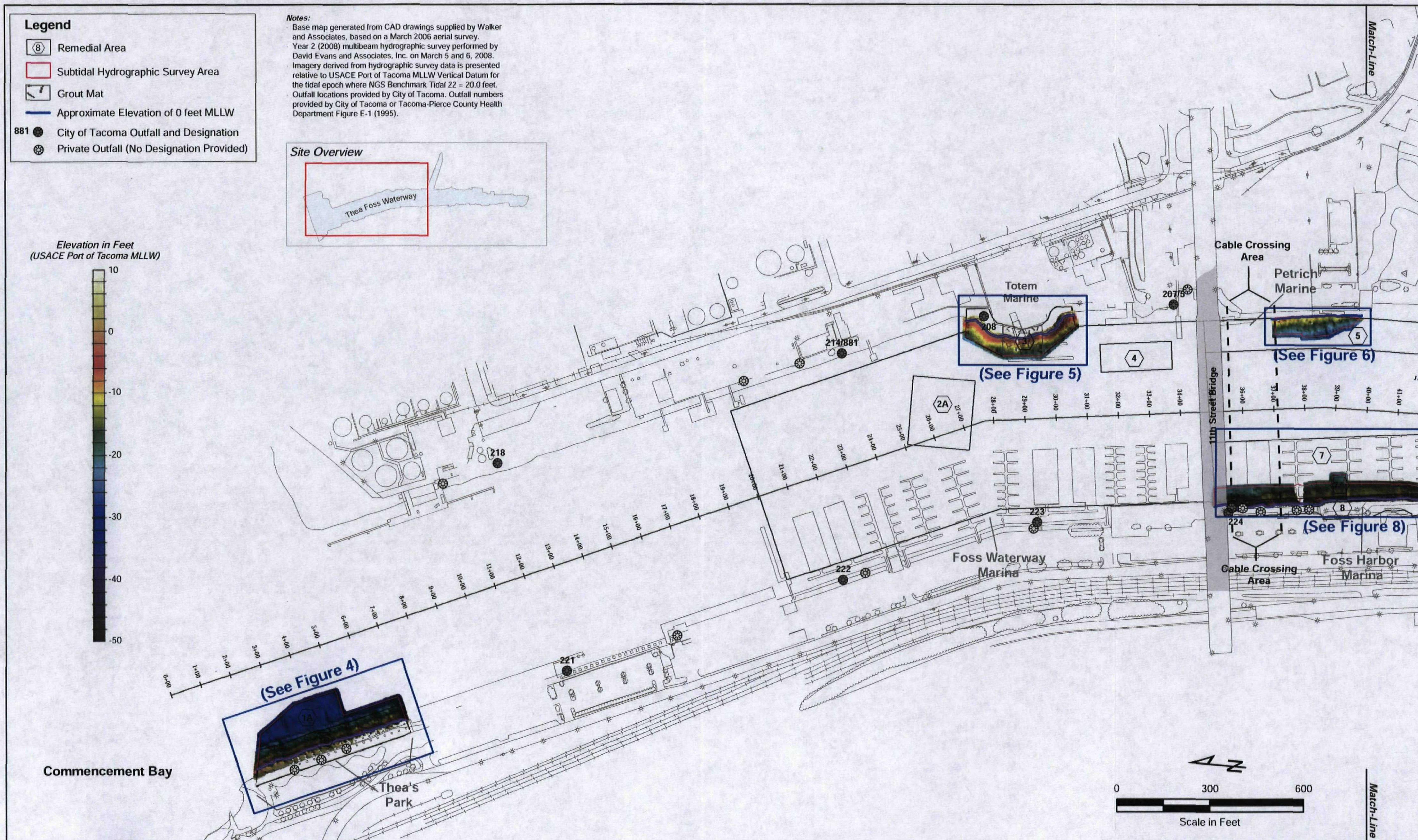

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Figure 3 (Page 1 of 2)
Overview of Year 2 (2008)
Bathymetric Conditions

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 3 (Overview of Year 2 (2008) Bathymetric Conditions (1of2)).mxd
Date: 4/26/2010

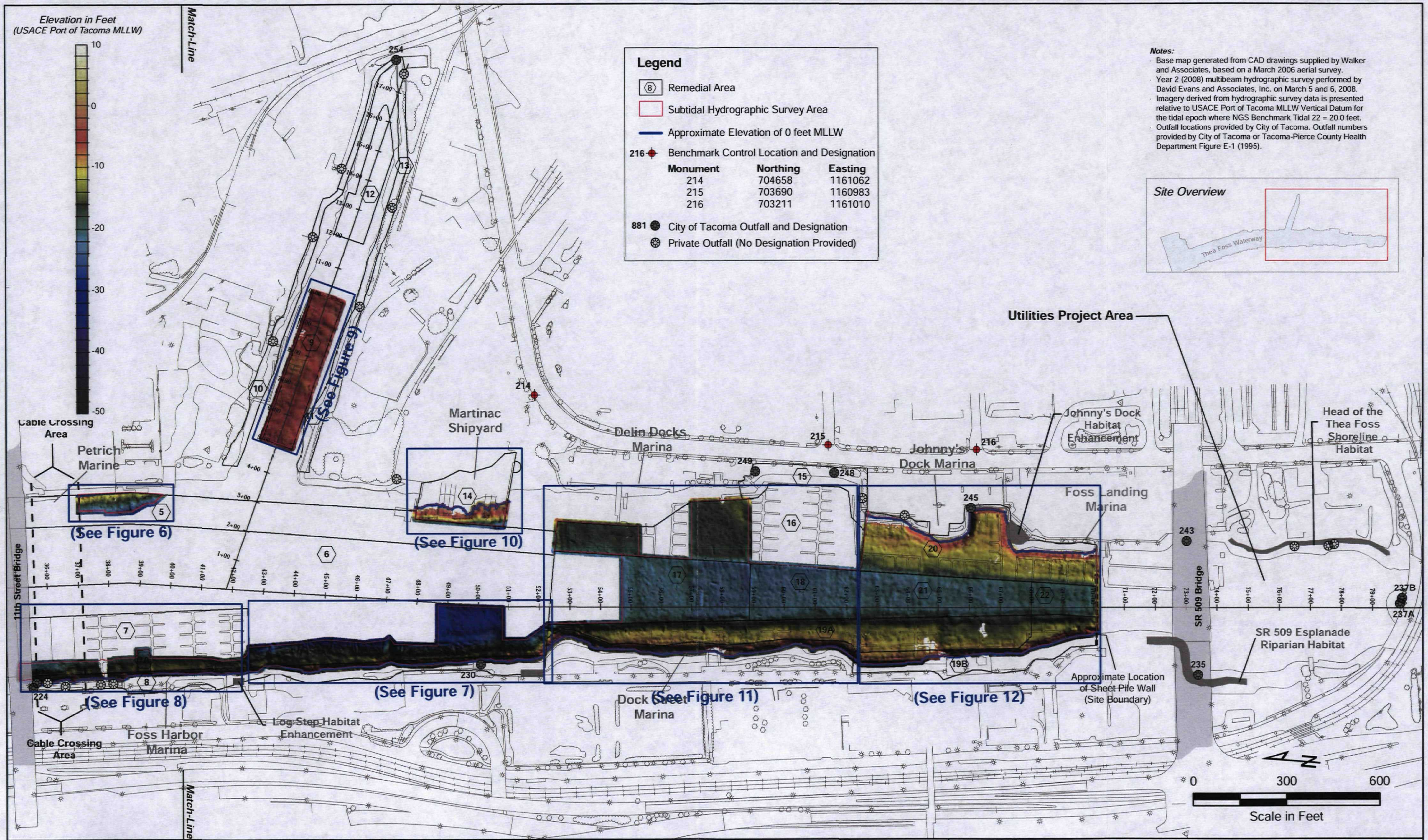

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**Figure 3 (Page 2 of 2)
Overview of Year 2 (2008)
Bathymetric Conditions**

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 3 (Overview of Year 2 (2008) Bathymetric Conditions (2of2)).mxd
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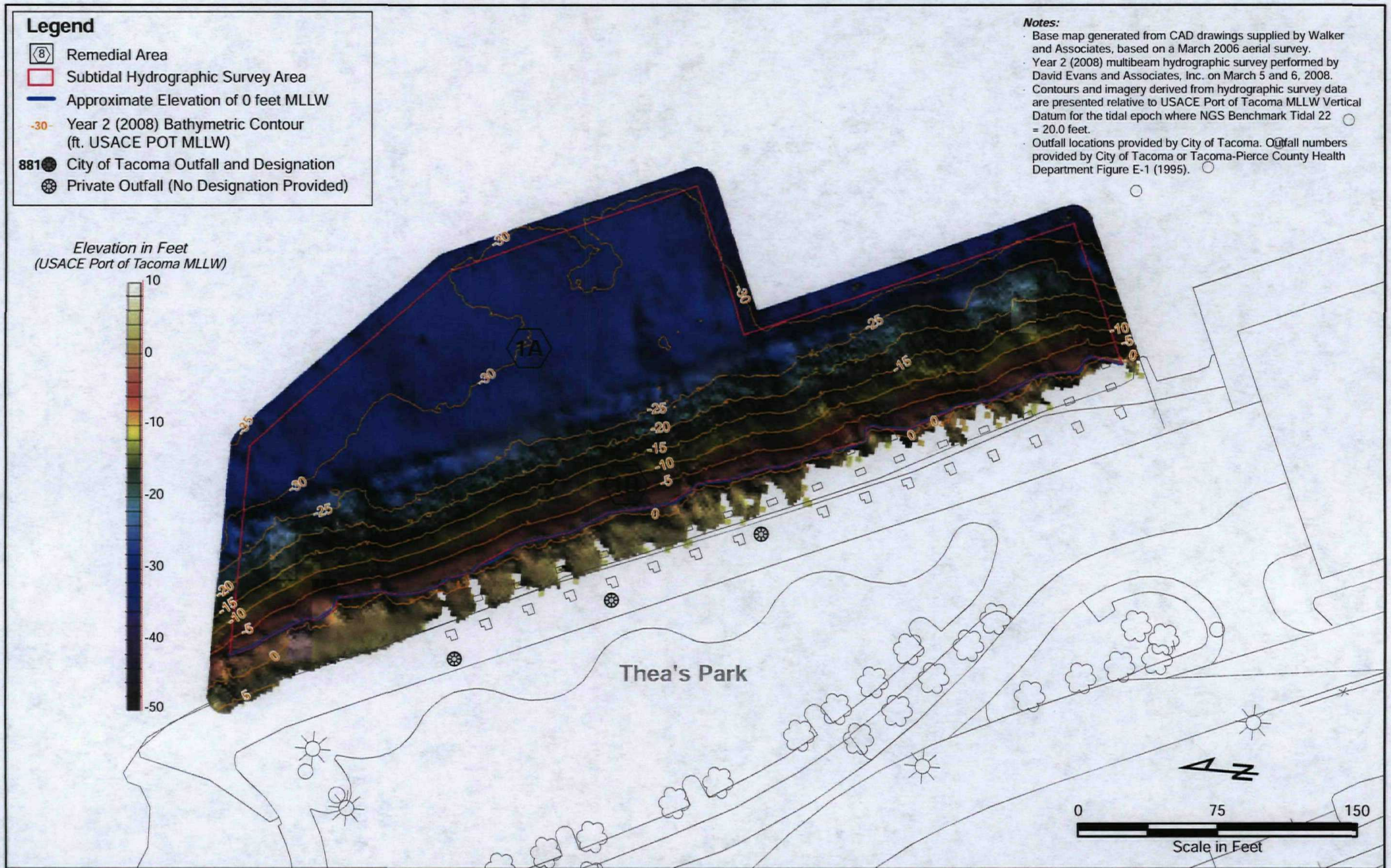

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Figure 4
RA 1 Year 2 (2008) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 4 (RA 1 Year 2 (2008) Subtidal Hydrographic Survey Results)Redux.mxd
Date: 4/19/2010

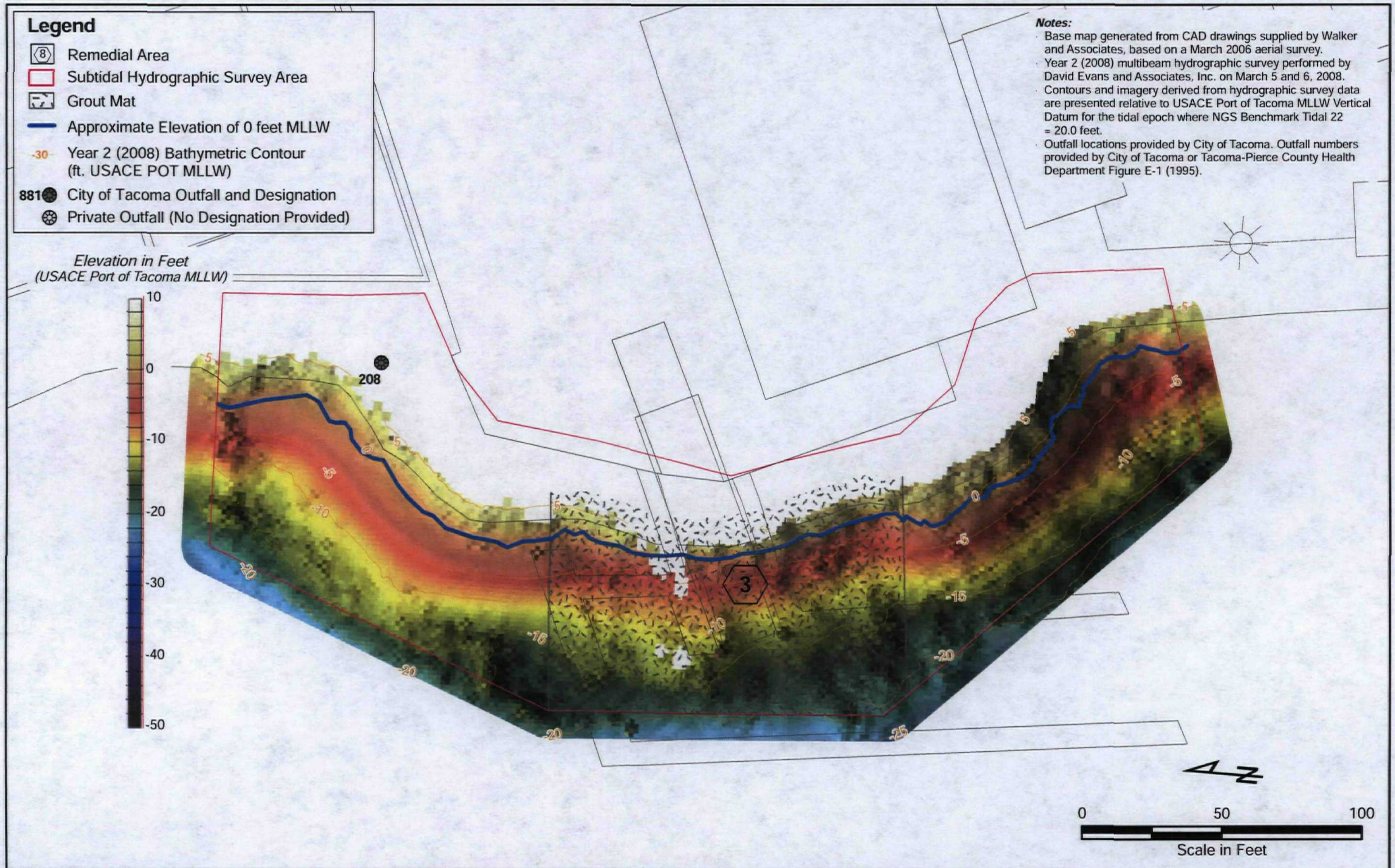

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Figure 5
RA 3 Year 2 (2008) Subtidal Hydrographic Survey Results

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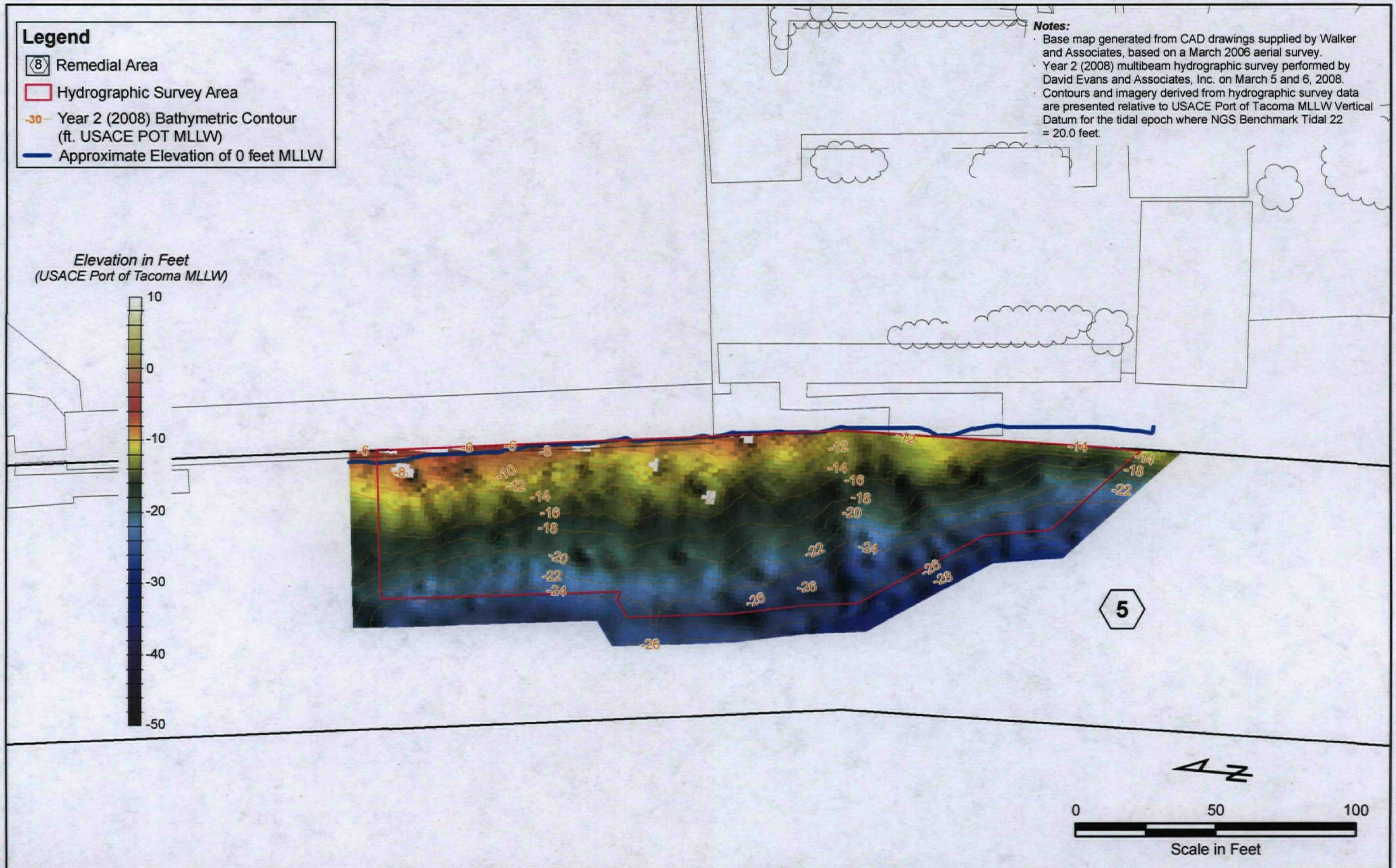

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Figure 6
RA 5 Year 2 (2008) Subtidal Hydrographic Survey Results

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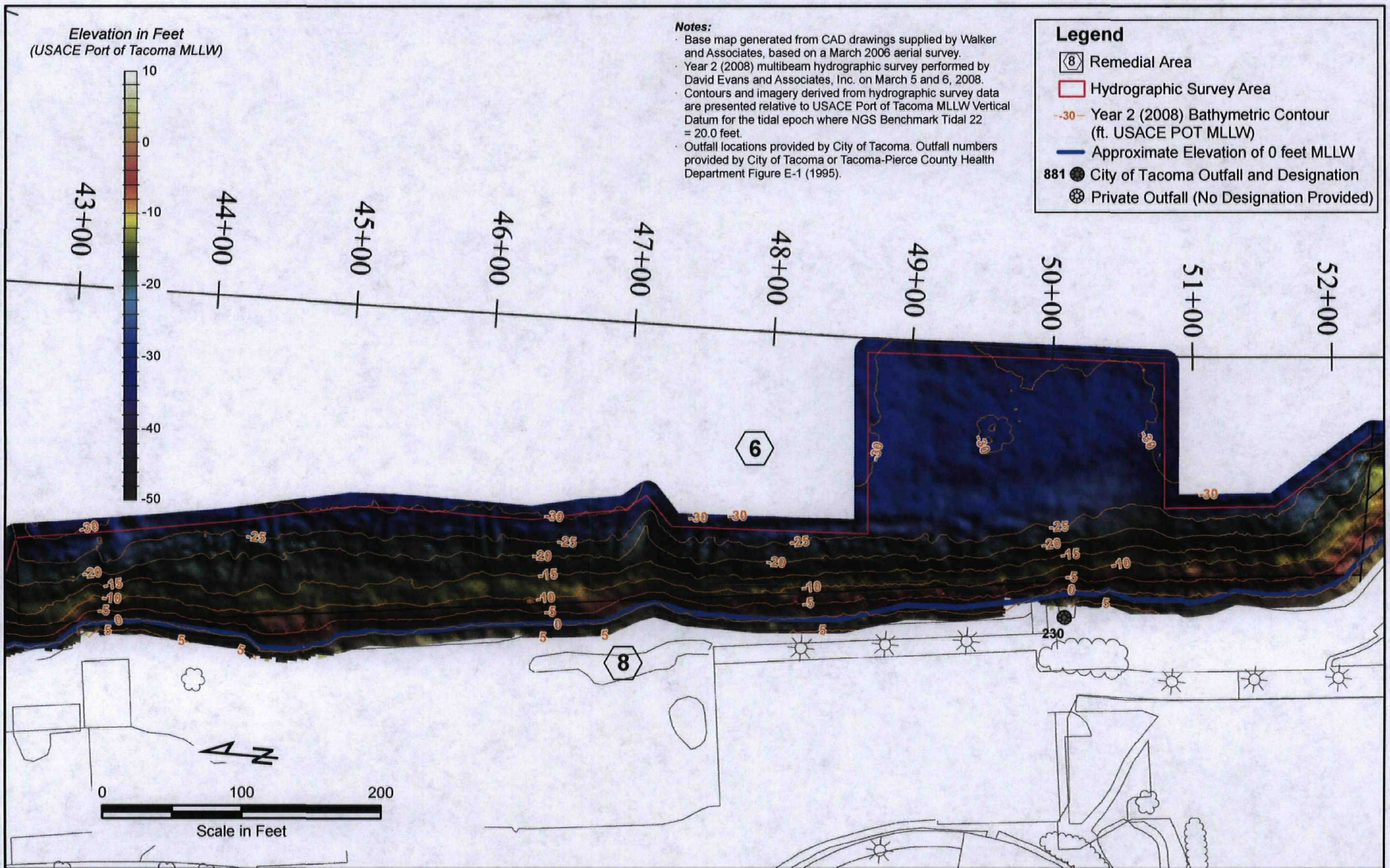

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Figure 7
RA 6 and Southern Portion of RA 8 Year 2 (2008) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 7 (RA 6 and Southern Portion of RA 8 Year 2 (2008) Subtidal Hydrographic Survey Results).mxd
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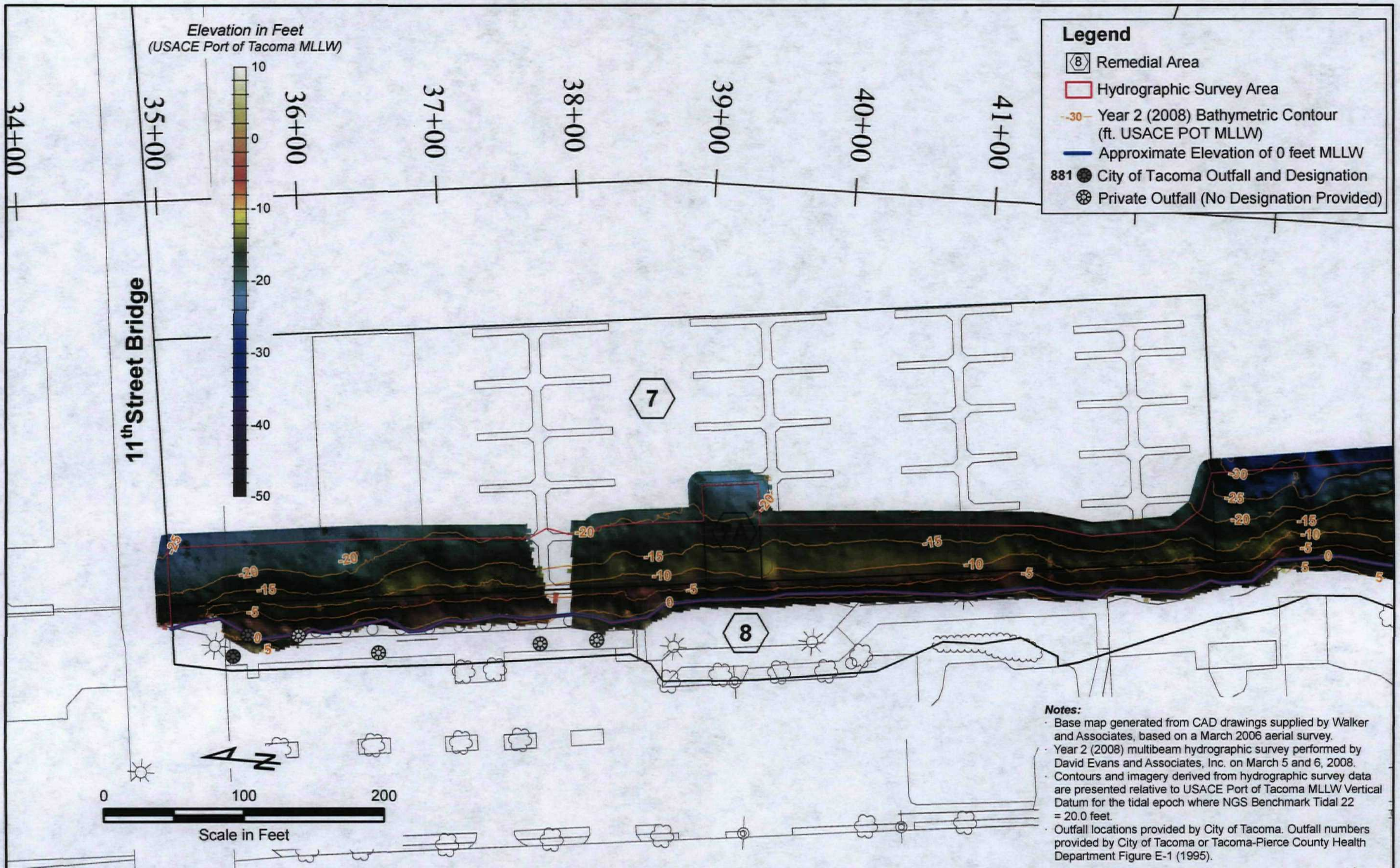

Notes:

- Base map generated from CAD drawings supplied by Walker and Associates, based on a March 2006 aerial survey.
- Year 2 (2008) multibeam hydrographic survey performed by David Evans and Associates, Inc. on March 5 and 6, 2008.
- Contours and imagery derived from hydrographic survey data are presented relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.
- Outfall locations provided by City of Tacoma. Outfall numbers provided by City of Tacoma or Tacoma-Pierce County Health Department Figure E-1 (1995).

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Figure 8
RA 7A and RA 8 Year 2 (2008) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 8 (RA 7A and RA 8 Year 2 (2008) Subtidal Hydrographic Survey Results).mxd
Date: 4/20/2010

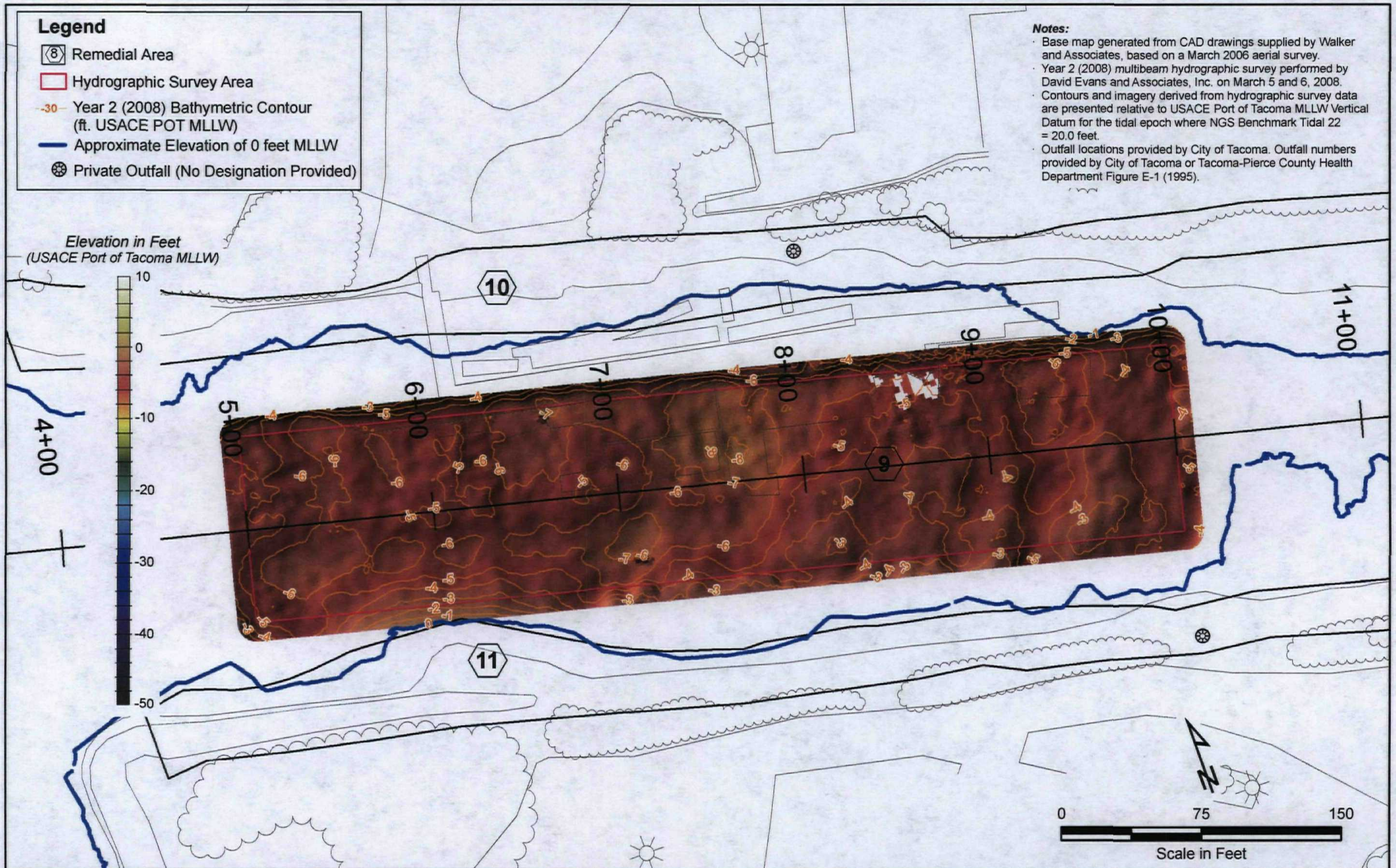

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Figure 9
RA 9 Year 2 (2008) Subtidal Hydrographic Survey Results

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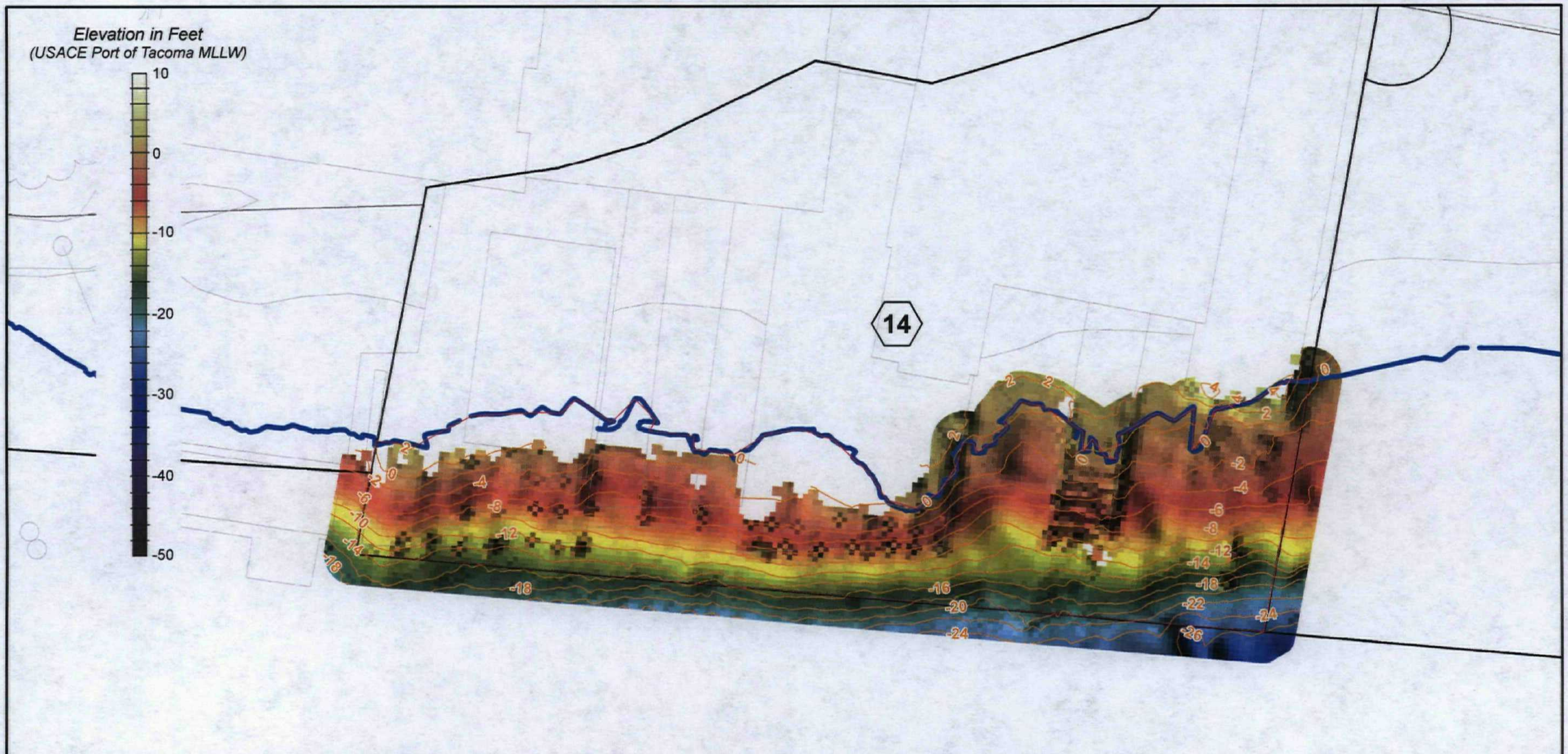

Legend

- 8 Remedial Area
- Hydrographic Survey Area
- -30 Year 2 (2008) Bathymetric Contour (ft. USACE POT MLLW)
- Approximate Elevation of 0 feet MLLW
- Private Outfall (No Designation Provided)

Notes:

- Base map generated from CAD drawings supplied by Walker and Associates, based on a March 2006 aerial survey.
- Year 2 (2008) multibeam hydrographic survey performed by David Evans and Associates, Inc. on March 5 and 6, 2008.
- Contours and imagery derived from hydrographic survey data are presented relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.
- Outfall locations provided by City of Tacoma. Outfall numbers provided by City of Tacoma or Tacoma-Pierce County Health Department Figure E-1 (1995).

N

0 50 100

Scale in Feet

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Figure 10
RA 14 Year 2 (2008) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 10 (RA 14 Year 2 (2008) Subtidal Hydrographic Survey Results).mxd
Date: 4/20/2010

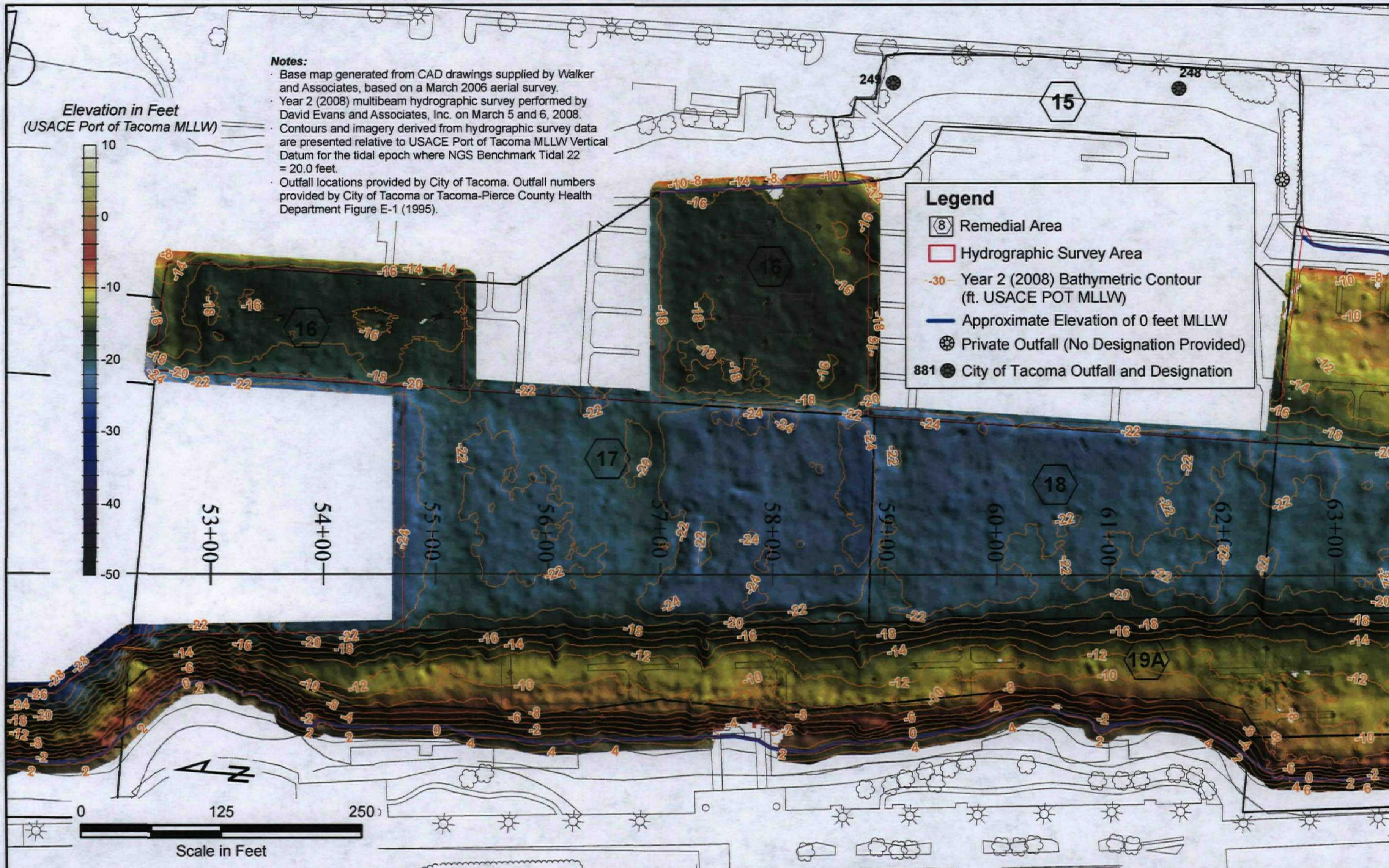

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Figure 11
RA 16, RA 17, RA 18, and RA 19A Year 2 (2008) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 11 (RA 16 17 18 19A Year 2 (2008) Subtidal Hydrographic Survey Results).mxd
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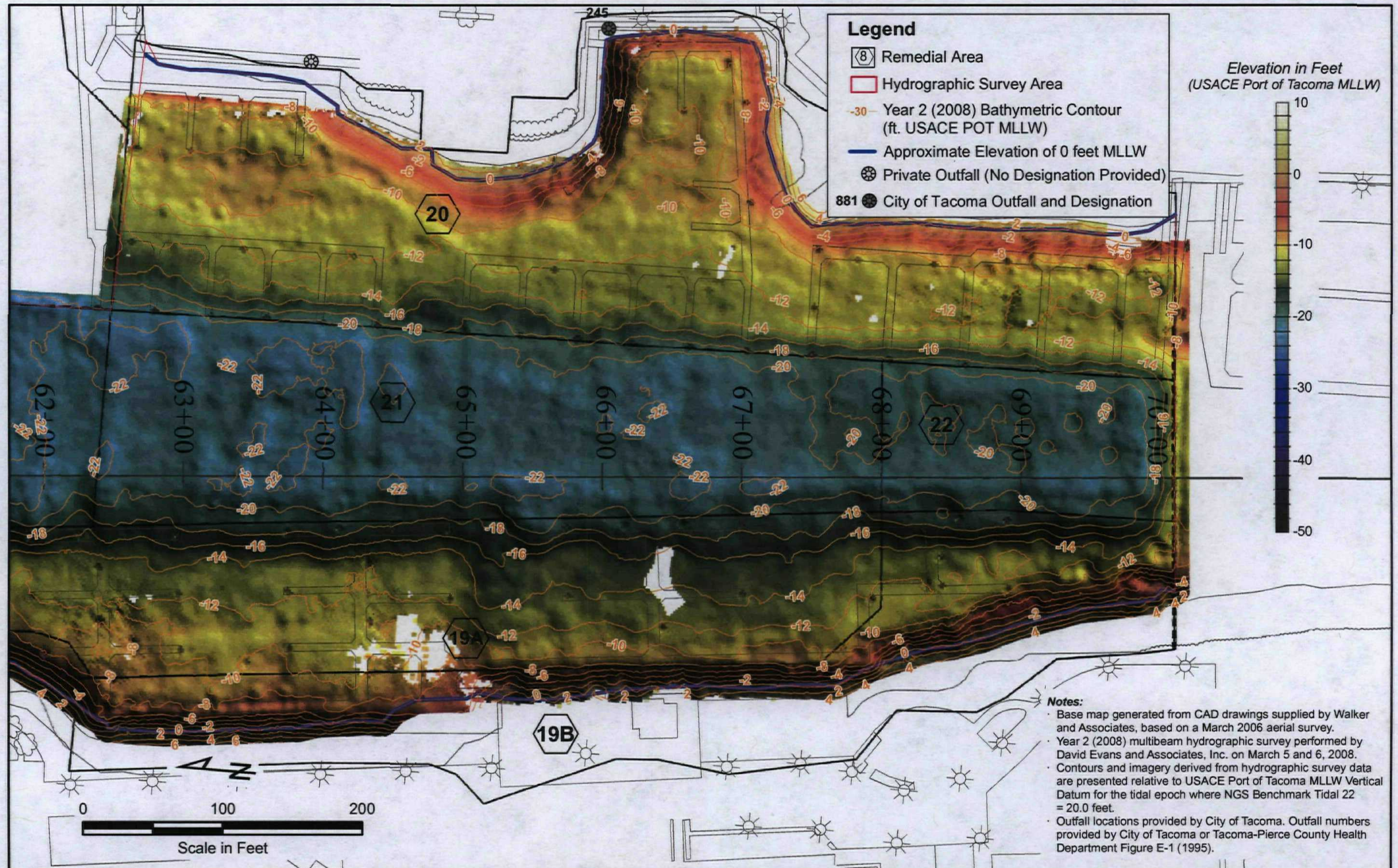

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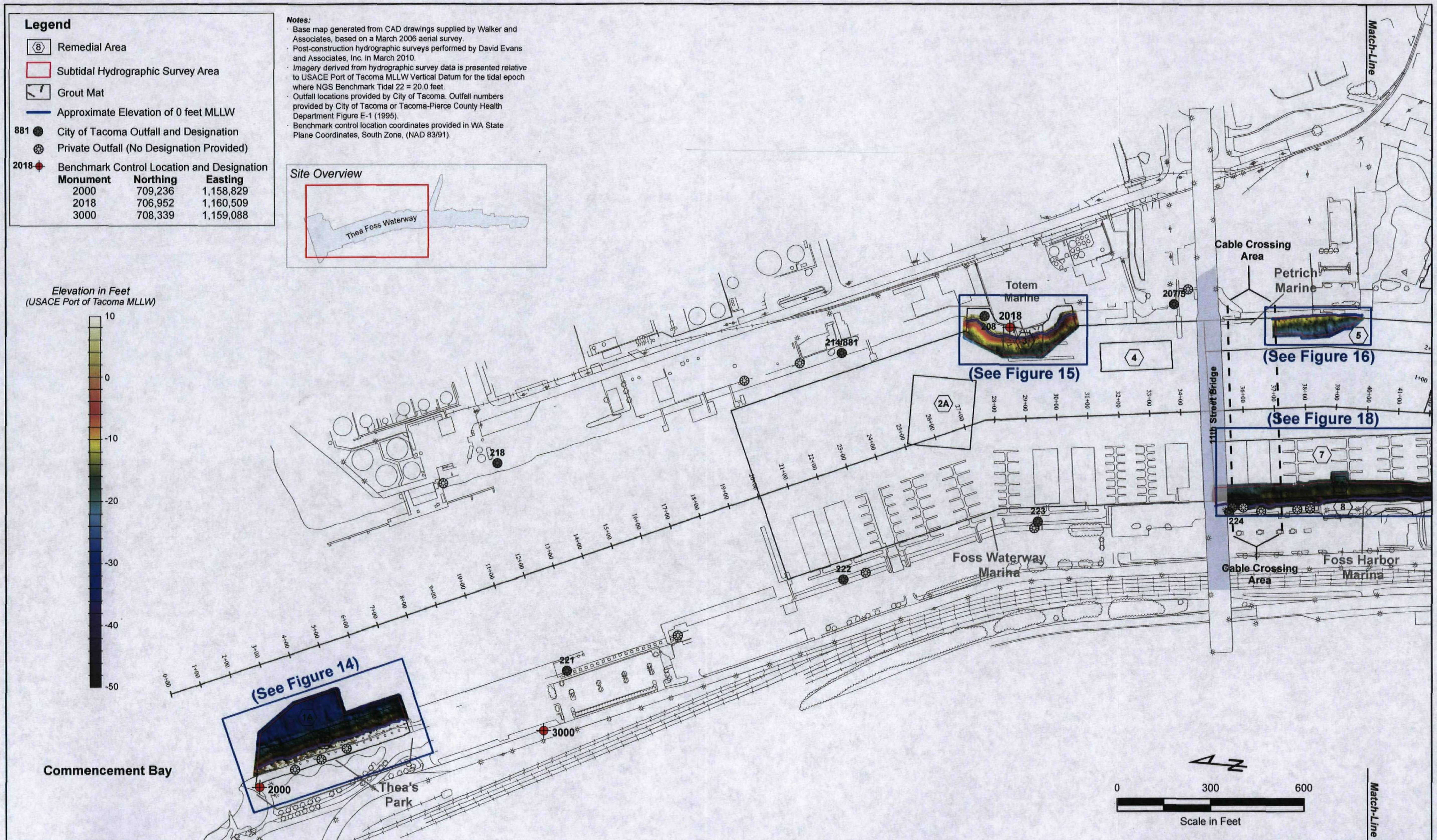
Figure 12
RA 19A, RA 19B, RA 20, RA 21 and RA 22 Year 2 (2008) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 12 (RA 19 19B 20 21 22 Year 2 (2008) Subtidal Hydrographic Survey Results).mxd
Date: 4/21/2010



Notes:

- Base map generated from CAD drawings supplied by Walker and Associates, based on a March 2006 aerial survey.
- Post-construction hydrographic surveys performed by David Evans and Associates, Inc. in March 2010.
- Imagery derived from hydrographic survey data is presented relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.
- Outfall locations provided by City of Tacoma. Outfall numbers provided by City of Tacoma or Tacoma-Pierce County Health Department Figure E-1 (1995).
- Benchmark control location coordinates provided in WA State Plane Coordinates, South Zone, (NAD 83/91).

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Figure 13 (Page 1 of 2)
Overview of Year 4 (2010) Bathymetric Conditions

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 13 (Overview of Year 4 (2010) Bathymetric Conditions (1 of 2)).mxd
Date: 5/10/2010

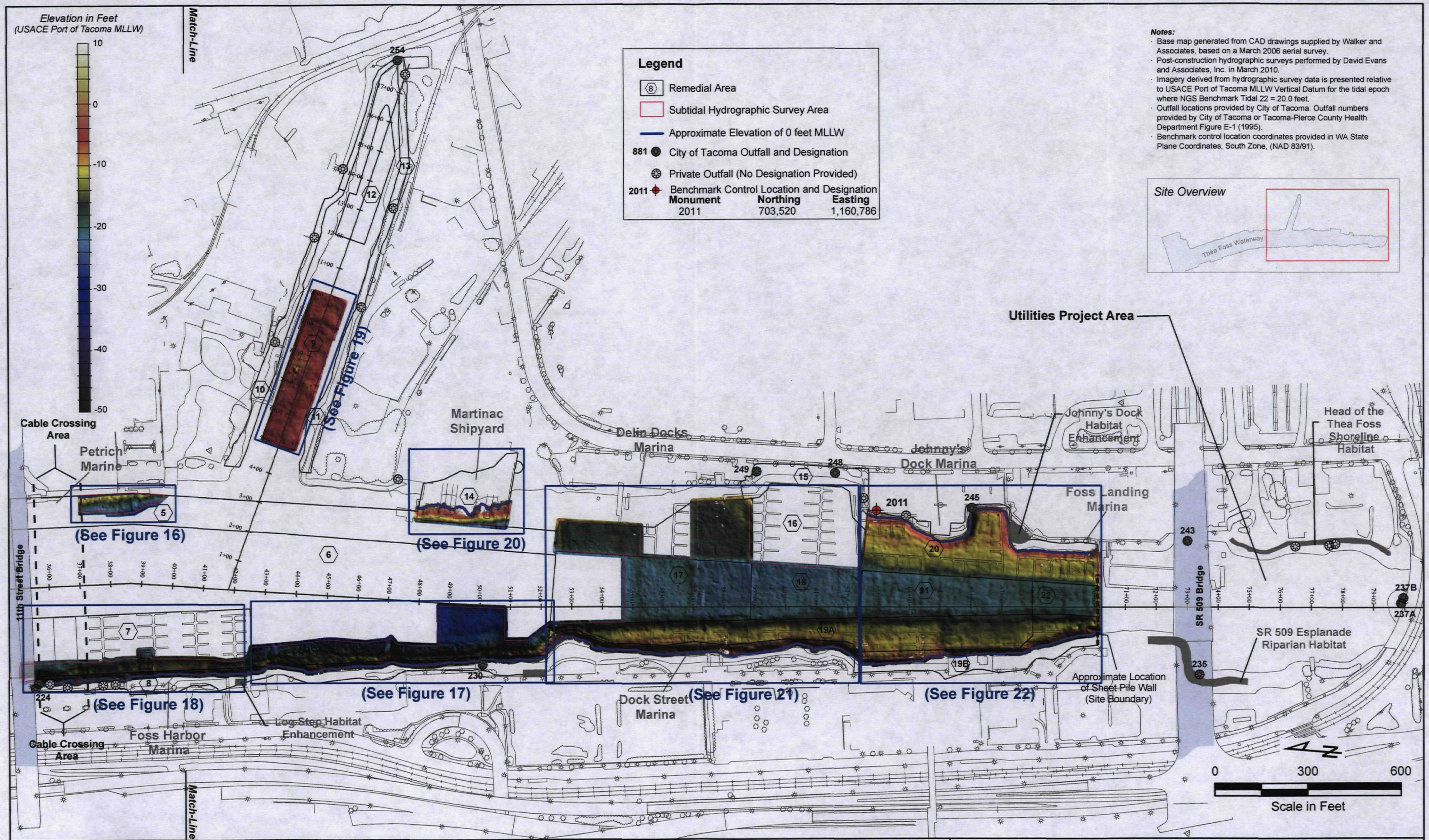

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Figure 13 (Page 2 of 2)
Overview of Year 4 (2010) Bathymetric Conditions

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 13 (Overview of Year 4 (2010) Bathymetric Conditions (2 of 2)).mxd
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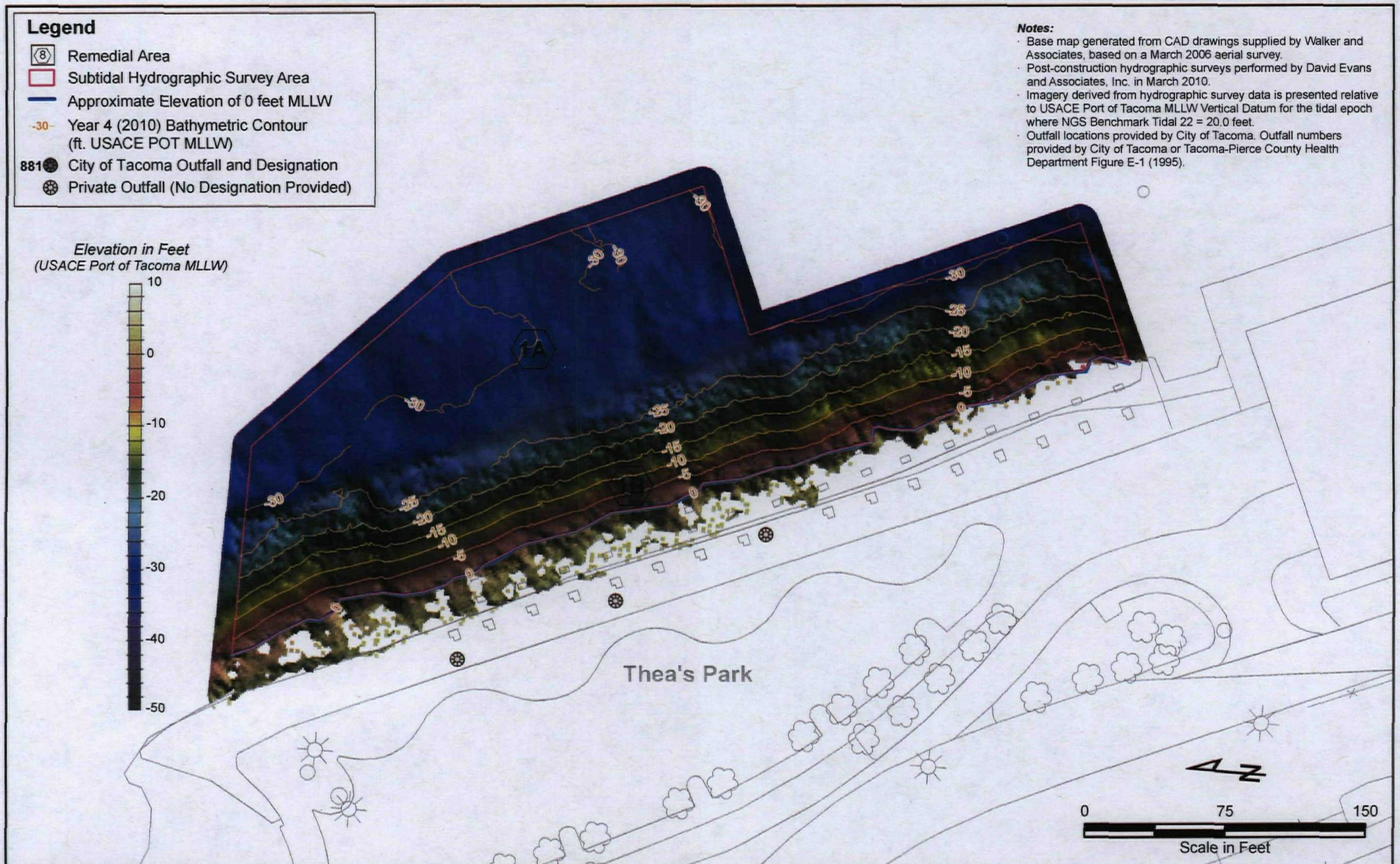

Notes:

- Base map generated from CAD drawings supplied by Walker and Associates, based on a March 2006 aerial survey.
- Post-construction hydrographic surveys performed by David Evans and Associates, Inc. in March 2010.
- Imagery derived from hydrographic survey data is presented relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.
- Outfall locations provided by City of Tacoma. Outfall numbers provided by City of Tacoma or Tacoma-Pierce County Health Department Figure E-1 (1995).

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Figure 14
RA 1 Year 4 (2010) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 14 (RA 1 Year 4 (2010) Subtidal Hydrographic Survey Results).mxd
Date: 4/21/2010

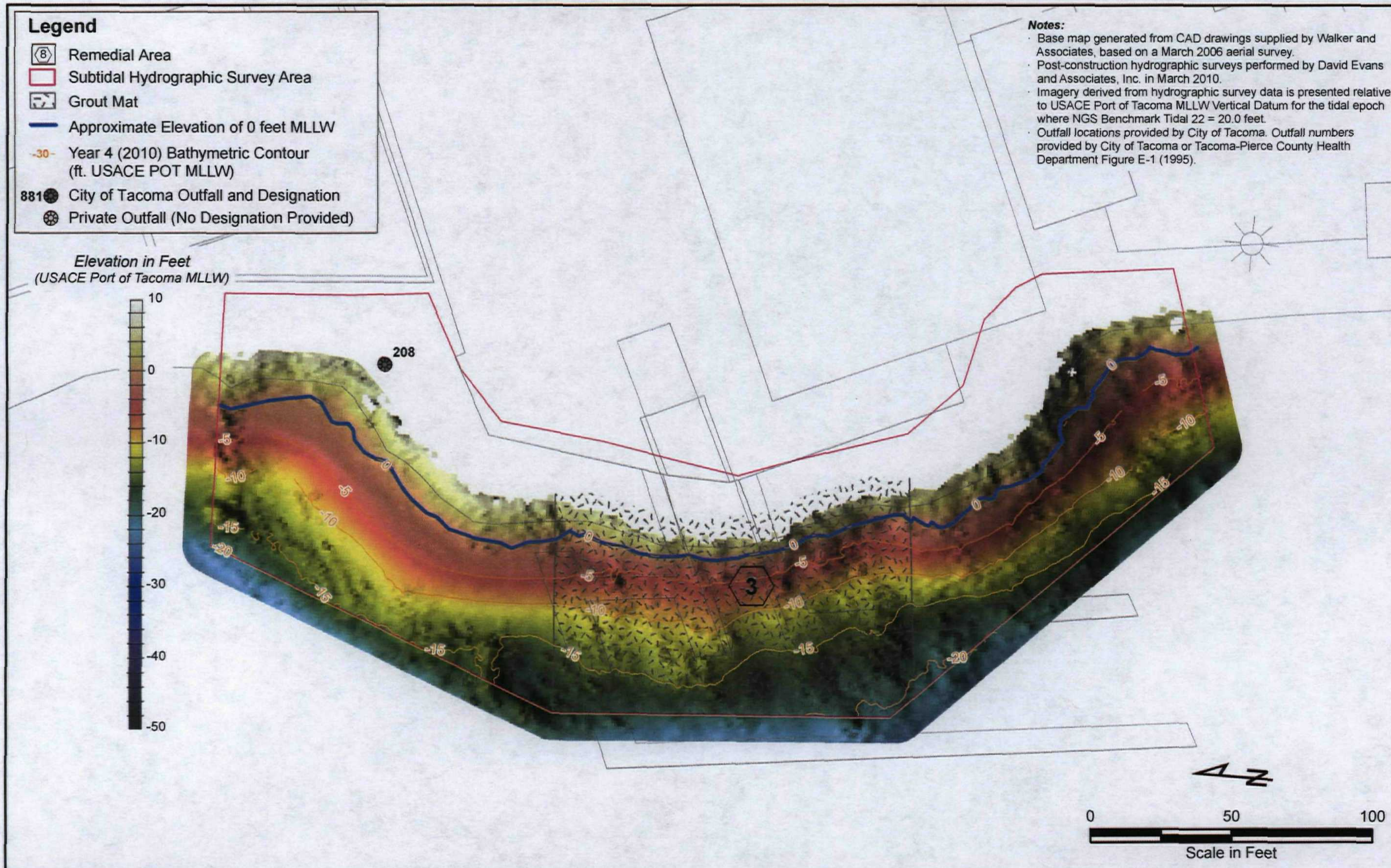

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Figure 15
RA 3 Year 4 (2010) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 15 (RA 3 Year 4 (2010) Subtidal Hydrographic Survey Results).mxd
Date: 4/23/2010

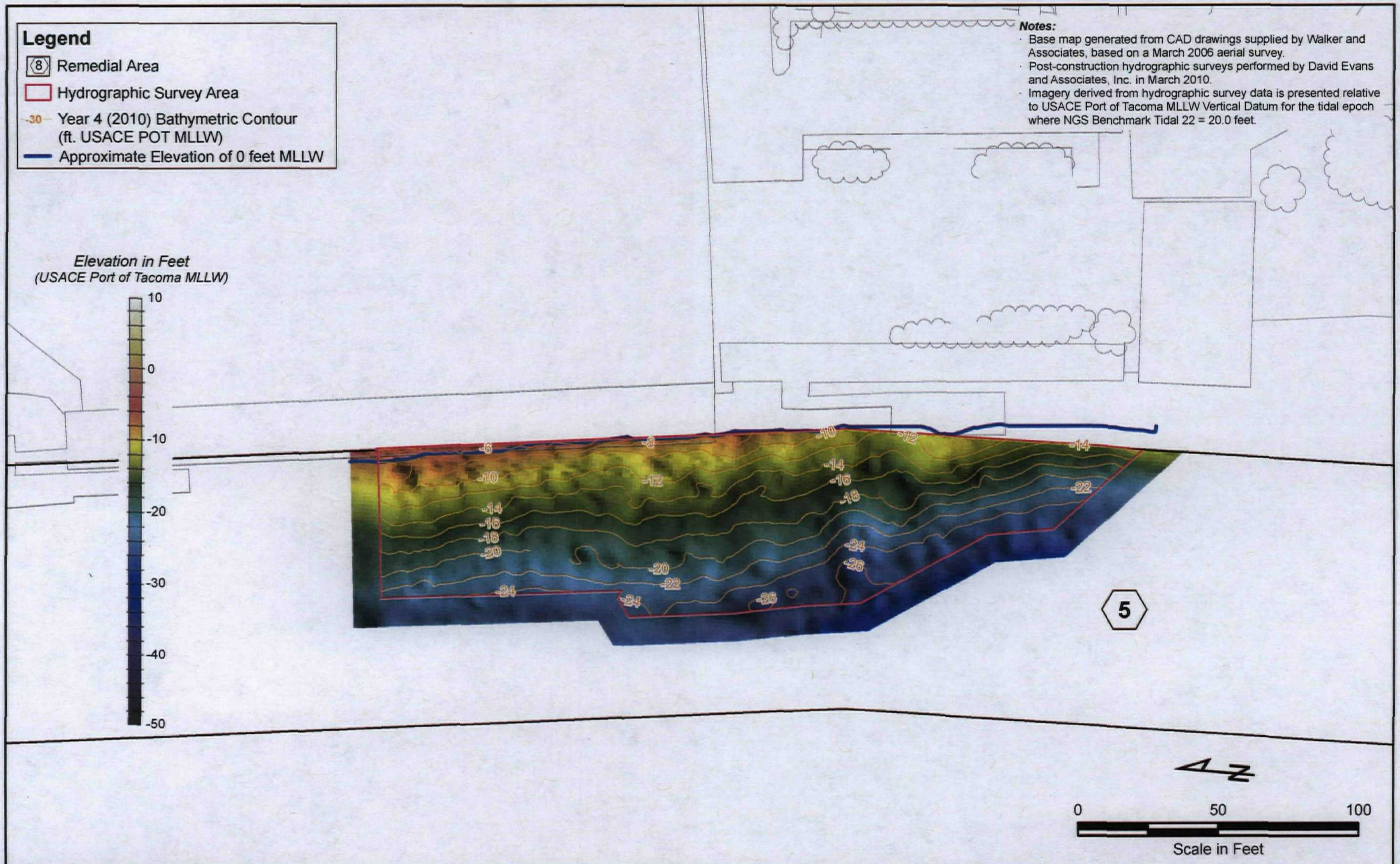

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Figure 16
RA 5 Year 4 (2010) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 16 (RA 5 Year 4 (2010) Subtidal Hydrographic Survey Results).mxd
Date: 4/23/2010

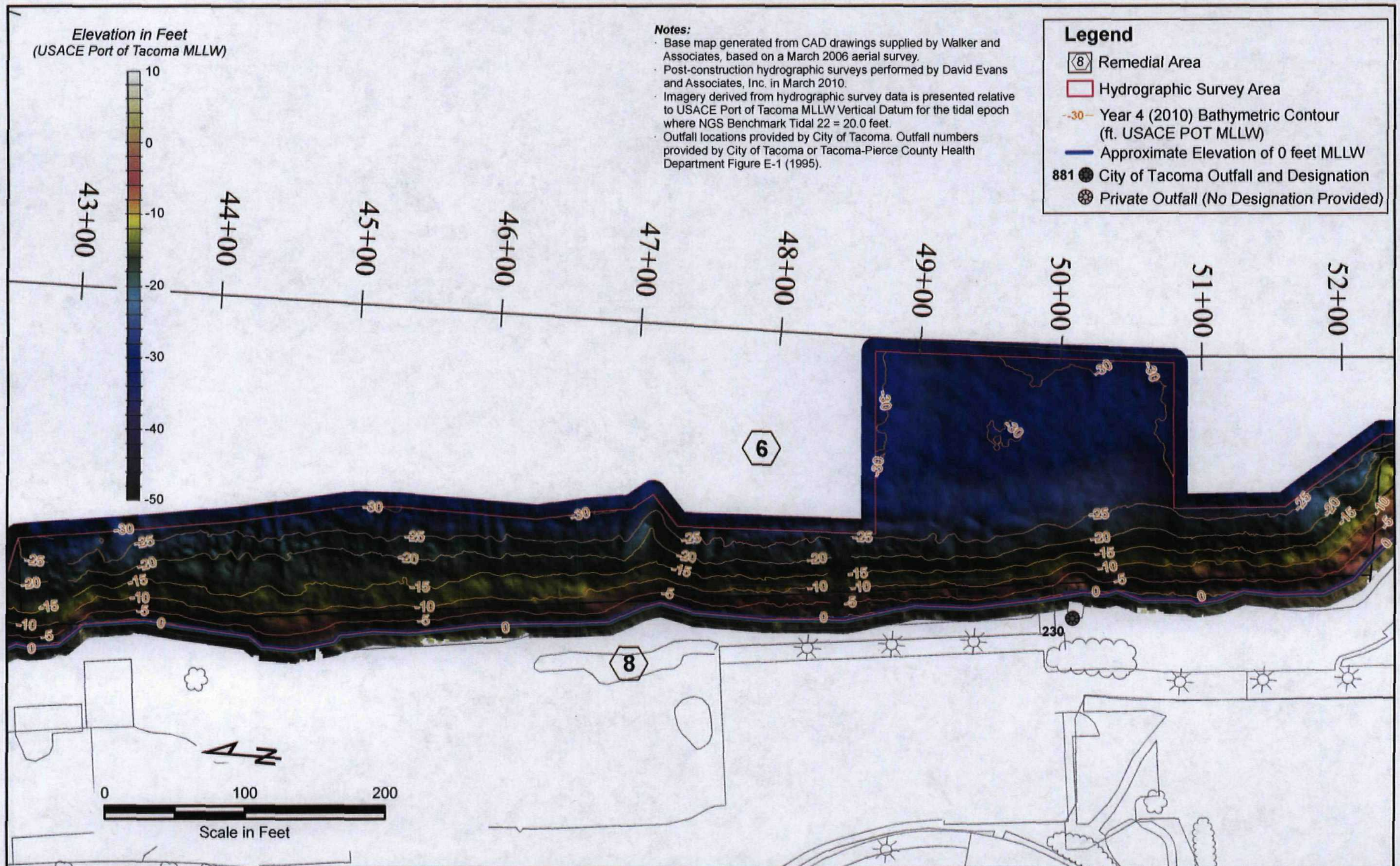

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Figure 17
RA 6 and Southern Portion of RA 8 Year 4 (2010) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 17 (RA 6 and Southern Portion of RA 8 Year 2 (2010) Subtidal Hydrographic Survey Results).mxd
Date: 4/23/2010

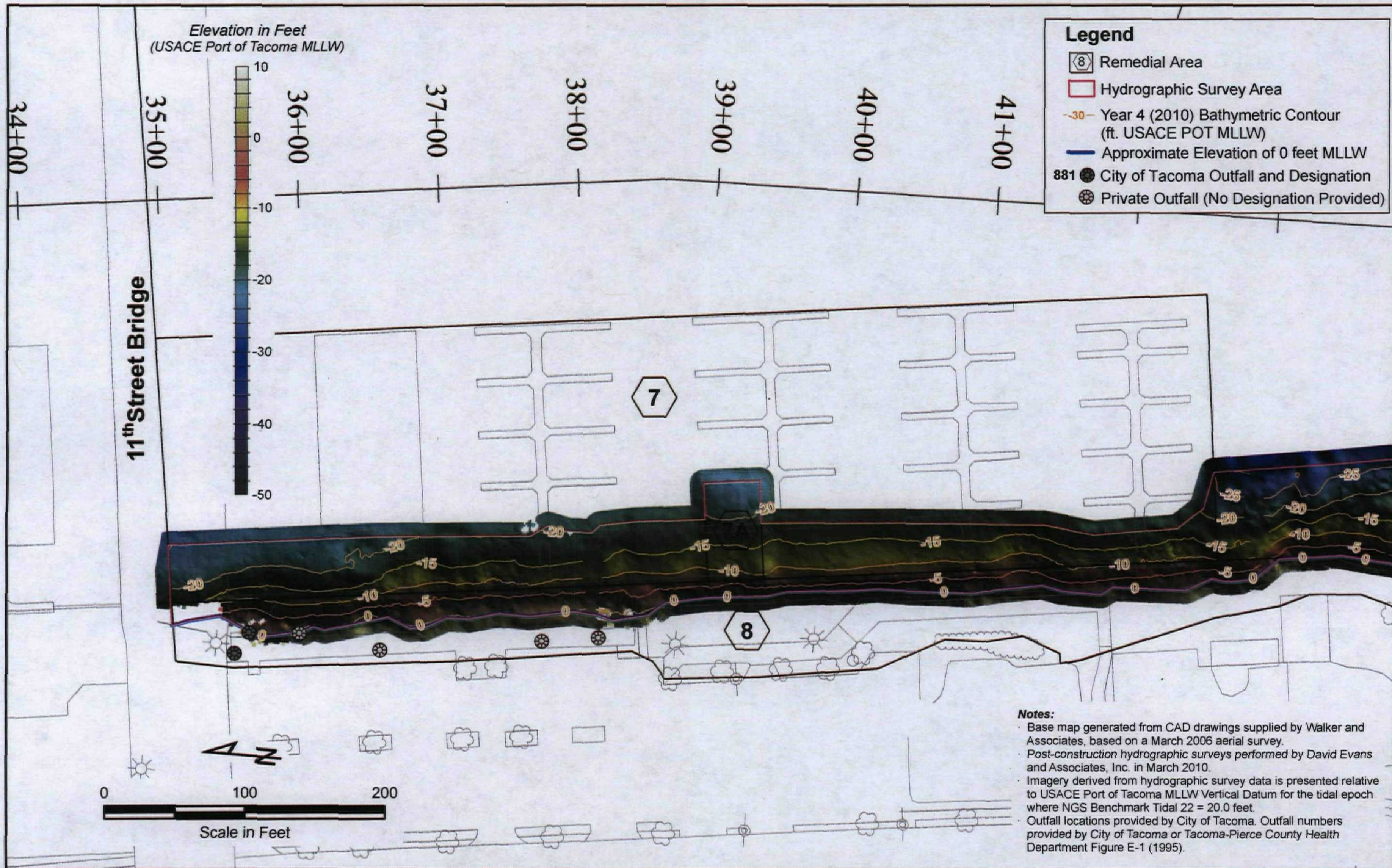

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Figure 18
RA 7A and RA 8 Year 4 (2010) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 18 (RA 7A and RA 8 Year 4 (2010) Subtidal Hydrographic Survey Results).mxd
Date: 4/23/2010

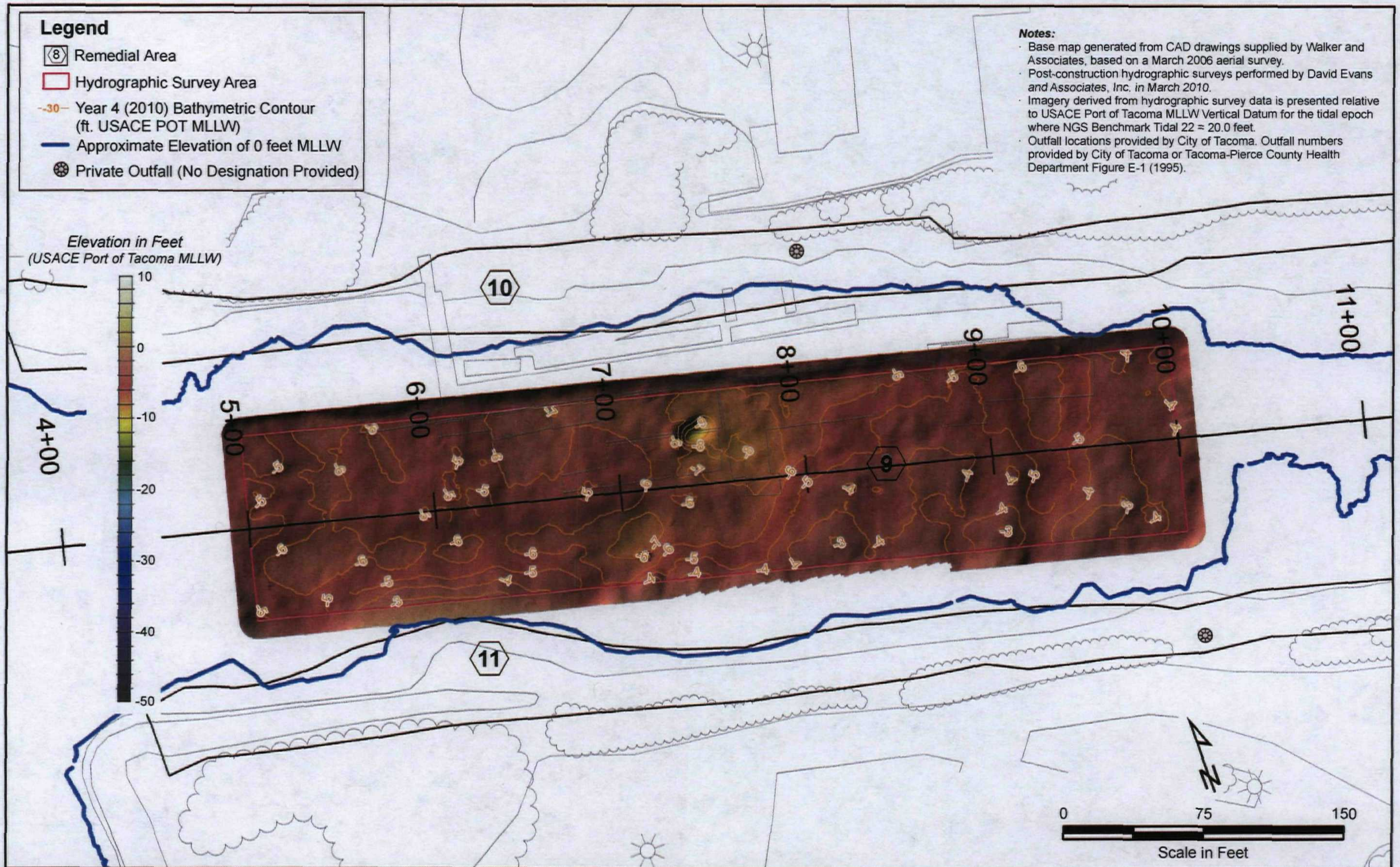

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Figure 19
RA 9 Year 4 (2010) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 19 (RA 9 Year 4 (2010) Subtidal Hydrographic Survey Results).mxd
Date: 4/23/2010

Legend

- (8) Remedial Area
- Hydrographic Survey Area
- -30 Year 4 (2010) Bathymetric Contour (ft. USACE POT MLLW)
- Approximate Elevation of 0 feet MLLW
- Private Outfall (No Designation Provided)

Notes:

- Base map generated from CAD drawings supplied by Walker and Associates, based on a March 2006 aerial survey.
- Year 2 (2008) multibeam hydrographic survey performed by David Evans and Associates, Inc. on March 5 and 6, 2008.
- Contours and imagery derived from hydrographic survey data are presented relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.
- Outfall locations provided by City of Tacoma. Outfall numbers provided by City of Tacoma or Tacoma-Pierce County Health Department Figure E-1 (1995).

0 50 100
Scale in Feet

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Figure 20
RA 14 Year 4 (2010) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 20 (RA 14 Year 4 (2010) Subtidal Hydrographic Survey Results).mxd
Date: 4/23/2010

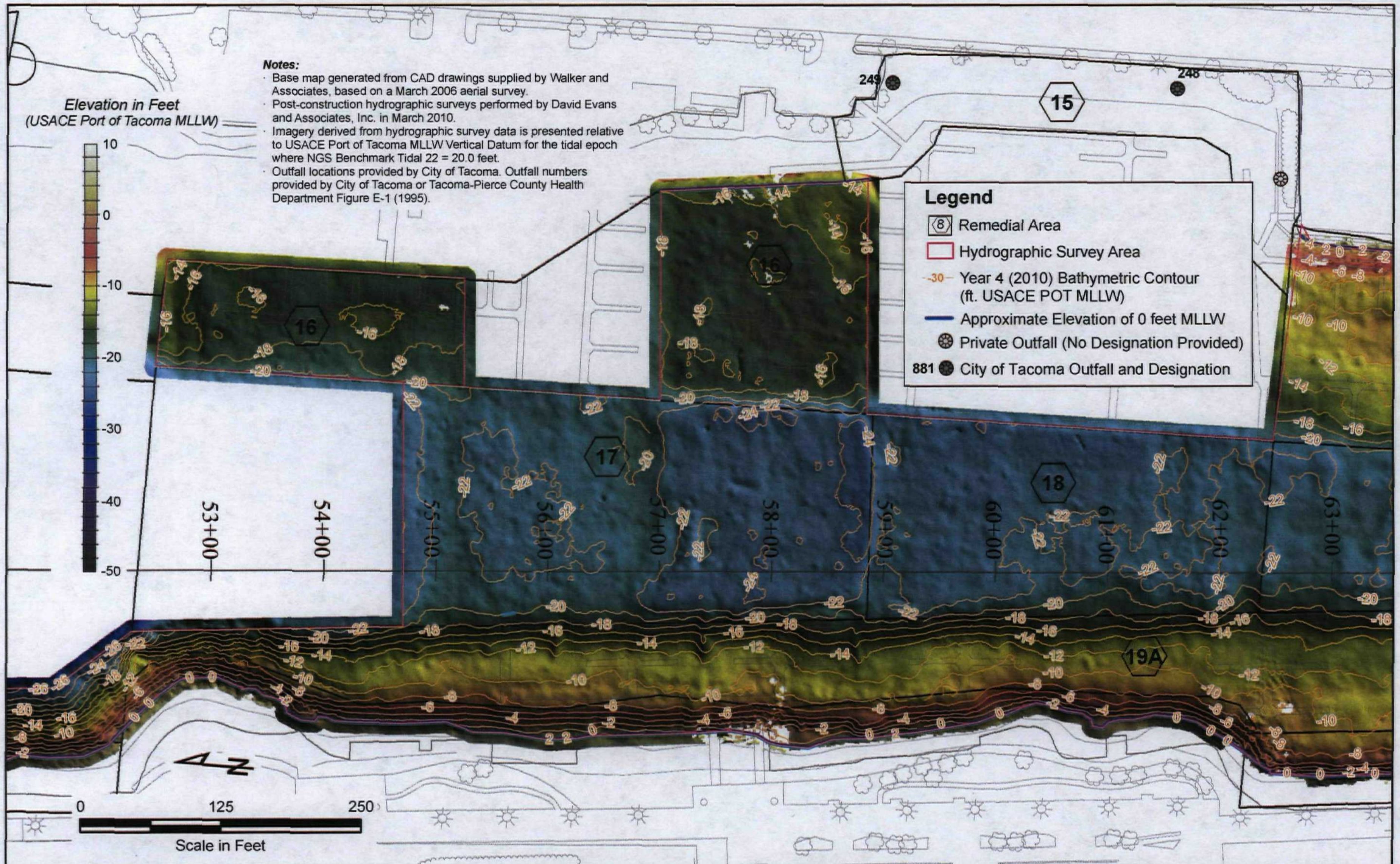

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Figure 21
RA 16, RA 17, RA 18, and RA 19A Year 4 (2010) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 21 (RA 16 17 18 19A Year 4 (2010) Subtidal Hydrographic Survey Results).mxd
Date: 4/23/2010

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Figure 22
RA 19A, RA 19B, RA 20, RA 21 and RA 22 Year 4 (2010) Subtidal Hydrographic Survey Results

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 22 (RA 19 19B 20 21 22 Year 4 (2010) Subtidal Hydrographic Survey Results).mxd
Date: 4/22/2010

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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1200 SIXTH AVENUE
SEATTLE, WA 98101

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File #: 23.6.11.2 V.16

Site Name: CBNSF

Figure 24 (Page 1 of 2)
Comparison of Year 2 (2008) and Year 4 (2010)
Subtidal Hydrographic Survey Results
And Cross Section Locations

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SEATTLE, WA 98101

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File #:	23.6.11.2 V.16
Site Name:	CBNSF

Figure 24 (Page 2 of 2)
Comparison of Year 2 (2008) and Year 4 (2010)
Subtidal Hydrographic Survey Results
And Cross Section Locations

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 SIXTH AVENUE
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Document Information

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File #:	23.6.11.2 V.16
Site Name:	CBNSF

Figure 23
Comparison of Baseline and Year 4 (2010)
Subtidal Hydrographic Survey Results
And Cross Section Locations

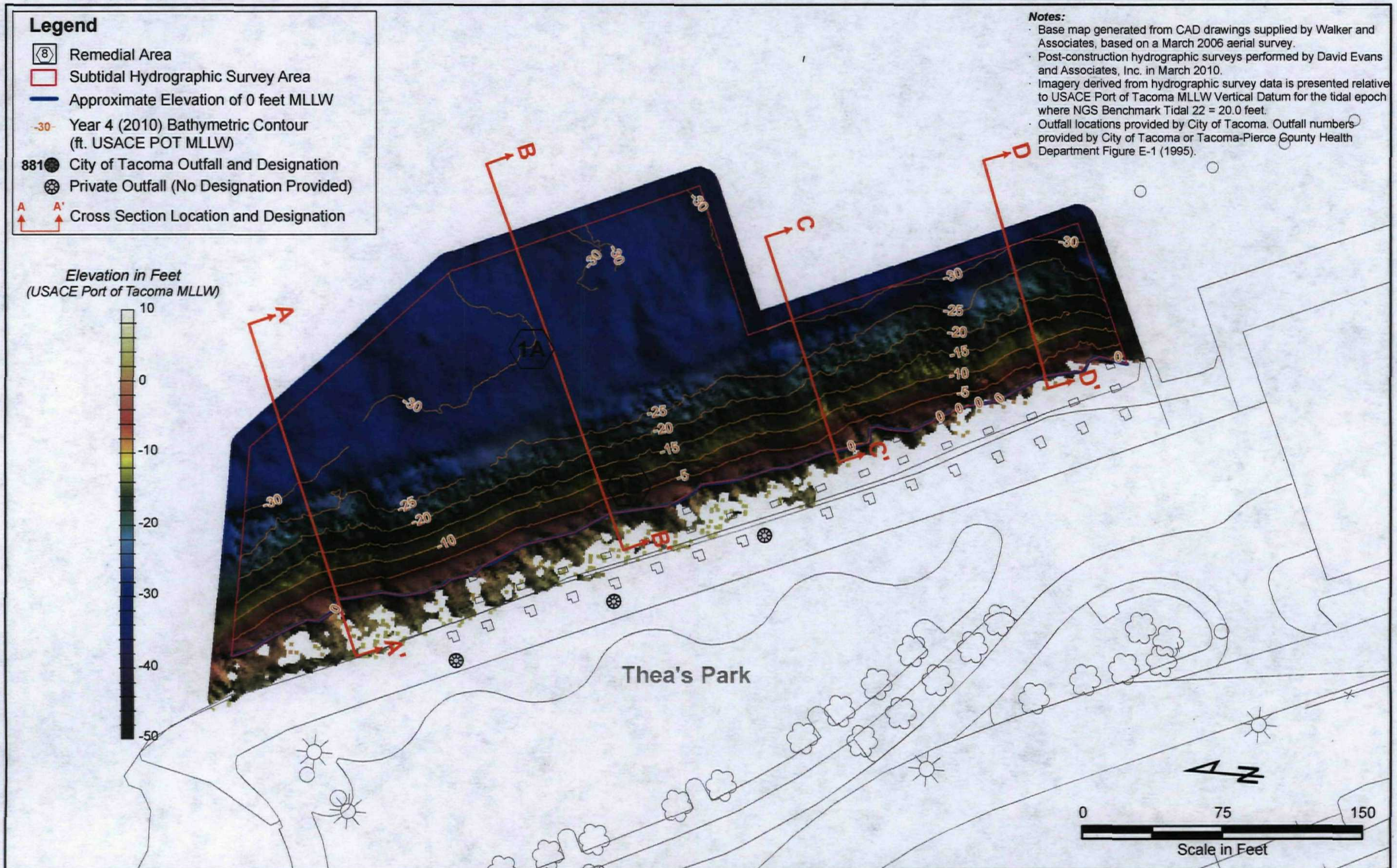

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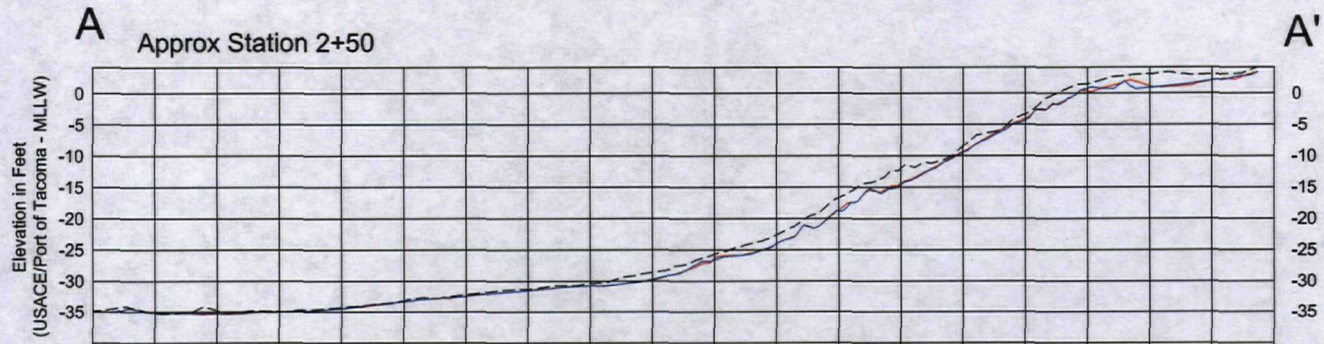
Figure 25
RA 1 Year 4 (2010) Locations of Bathymetric Cross Sections

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 25 (RA 1 Locations of Bathymetric Cross-Sections over Year 4 (2010) Bathymetric Data).mxd
Date: 4/26/2010

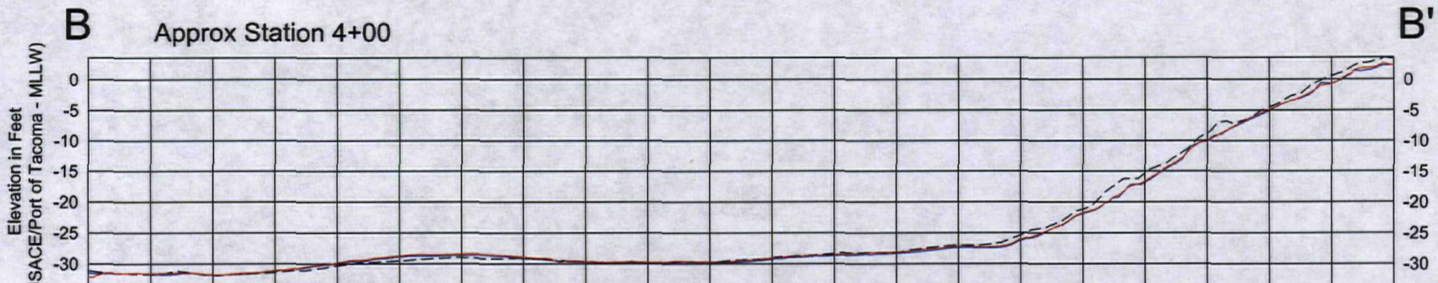
DWG NAME: G:\project\Clients\Floyd and Snider\Thea Foss\CAD2010\2010FSTheaFoss001.dwg
DATE: 6/1/2010 7:20 AM

A Approx Station 2+50 A'



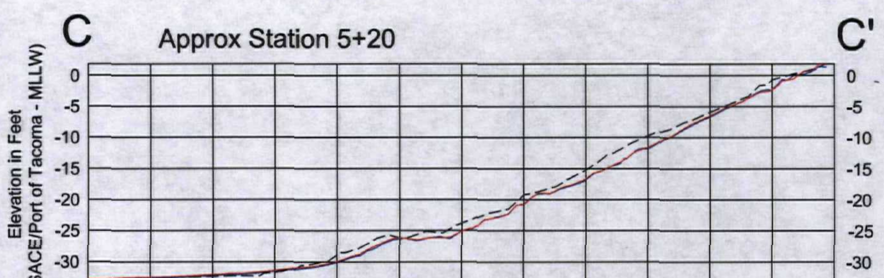
	0+10.00	0+20.00	0+30.00	0+40.00	0+50.00	0+60.00	0+70.00	0+80.00	0+90.00	1+00.00	1+10.00	1+20.00	1+30.00	1+40.00	1+50.00	1+60.00	1+70.00	1+80.00	1+90.00
Baseline (2003) SB	-35.2	-34.8	-34.9	-34.3	-33.2	-32.2	-31.4	-30.4	-28.6	-25.7	-22.6	-16.7	-12.0	-8.5	-3.3	1.5	3.1	3.0	
Year-2 (2008) MB	-35.1	-35.2	-35.0	-34.4	-33.4	-32.5	-31.5	-30.8	-29.7	-26.5	-24.0	-18.8	-14.6	-9.5	-4.3	0.8	0.9	2.1	
Year-4 (2010) MB	-35.2	-35.3	-35.1	-34.5	-33.3	-32.5	-31.5	-30.8	-29.8	-26.3	-24.0	-18.6	-14.4	-9.3	-4.0	0.3	1.2	2.1	3.3
Change in Elev (Baseline to Y4)	0	-0.5	-0.2	-0.2	-0.1	-0.3	-0.1	-0.4	-1.2	-0.6	-1.4	-1.9	-2.4	-0.8	-0.7	-1.2	-1.9	-0.9	
Change in Elev (Y2 to Y4)	-0.1	-0.1	-0.1	-0.1	+0.1	0	0	0	-0.1	+0.2	0	+0.2	+0.2	+0.2	+0.3	-0.5	+0.3	0	

B Approx Station 4+00 B'



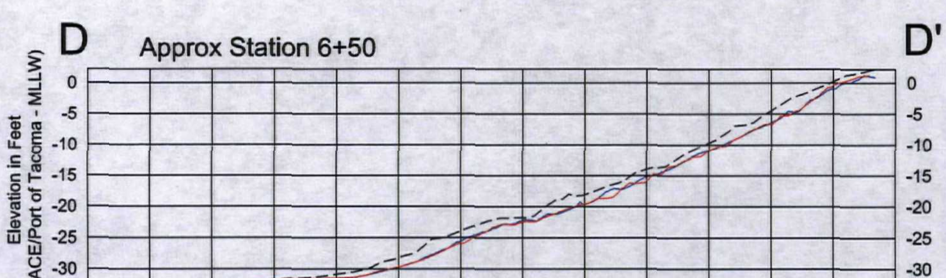
	0+10.00	0+20.00	0+30.00	0+40.00	0+50.00	0+60.00	0+70.00	0+80.00	0+90.00	1+00.00	1+10.00	1+20.00	1+30.00	1+40.00	1+50.00	1+60.00	1+70.00	1+80.00	1+90.00	2+00.00	2+10.00
Baseline (2003) SB	-31.7	-31.9	-31.4	-30.3	-29.6	-29.0	-29.1	-29.7	-29.8	-29.7	-29.1	-28.4	-28.1	-27.0	-25.4	-21.2	-15.4	-8.8	-4.5	0.5	3.3
Year-2 (2008) MB	-31.7	-31.8	-31.2	-30.0	-28.9	-28.6	-29.1	-29.8	-29.9	-29.8	-29.3	-28.7	-28.3	-27.4	-26.2	-21.9	-16.9	-10.0	-5.1	-0.8	2.2
Year-4 (2010) MB	-31.7	-31.9	-31.3	-30.0	-28.9	-28.6	-29.0	-29.8	-29.9	-29.8	-29.2	-28.7	-28.2	-27.3	-26.2	-21.9	-16.8	-10.1	-5.0	-0.9	2.1
Change in Elev (Baseline to Y4)	0	0	+0.1	+0.3	+0.7	+0.4	+0.1	-0.1	-0.1	-0.1	-0.1	-0.3	-0.1	-0.3	-0.8	-0.7	-1.4	-1.3	-0.5	-1.4	-1.2
Change in Elev (Y2 to Y4)	0	-0.1	-0.1	0	0	0	+0.1	0	0	0	+0.1	0	+0.1	+0.1	0	0	+0.1	-0.1	+0.1	-0.1	-0.1

C Approx Station 5+20 C'



	1+00.00	1+10.00	1+20.00	1+30.00	1+40.00	1+50.00	1+60.00	1+70.00	1+80.00	1+90.00	2+00.00	2+10.00
Baseline (2003) SB	-32.5	-32.3	-31.7	-28.9	-26.1	-23.8	-19.2	-15.1	-9.8	-5.9	-0.7	
Year-2 (2008) MB	-32.6	-32.2	-31.5	-30.1	-26.3	-25.0	-20.7	-16.6	-11.8	-6.6	-2.2	
Year-4 (2010) MB	-32.5	-32.0	-31.4	-30.0	-26.2	-25.1	-20.7	-16.6	-11.6	-6.5	-2.3	
Change in Elev (Baseline to Y4)	0	+0.3	+0.3	-1.1	-0.1	-1.3	-1.5	-1.5	-1.8	-0.6	-1.6	
Change in Elev (Y2 to Y4)	+0.1	+0.2	+0.1	+0.1	+0.1	-0.1	0	0	+0.2	+0.1	-0.1	

D Approx Station 6+50 D'



	0+10.00	0+20.00	0+30.00	0+40.00	0+50.00	0+60.00	0+70.00	0+80.00	0+90.00	1+00.00	1+10.00	1+20.00	1+30.00
Baseline (2003) SB	-33.2	-32.8	-31.8	-30.9	-28.2	-24.0	-21.8	-18.1	-14.0	-9.7	-4.5	0.2	
Year-2 (2008) MB	-33.2	-32.9	-32.2	-31.5	-29.6	-25.6	-22.2	-19.5	-15.2	-10.9	-6.4	-1.0	
Year-4 (2010) MB	-33.2	-32.8	-32.0	-31.4	-29.7	-25.8	-22.5	-19.5	-15.9	-10.8	-6.6	-0.4	
Change in Elev (Baseline to Y4)	0	0	-0.2	-0.5	-1.5	-1.8	-0.7	-1.4	-1.9	-1.1	-2.1	-0.6	
Change in Elev (Y2 to Y4)	0	+0.1	+0.2	+0.1	-0.1	-0.2	-0.3	0	-0.7	+0.1	-0.2	+0.6	

NOTES:

1. Baseline (2003) Single Beam Survey performed by Parametrix. (Feb., 2003)
2. Year 2 (2008) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2008)
3. Year 4 (2010) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2010)
4. Contours and imagery derived from bathymetric data are presented in units of feet relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.

0 30 60
Scale in Feet

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Figure 26
RA 1 Comparison of Year 4 to Baseline and Year 2 Subtidal Hydrographic Capped Area Cross Sections

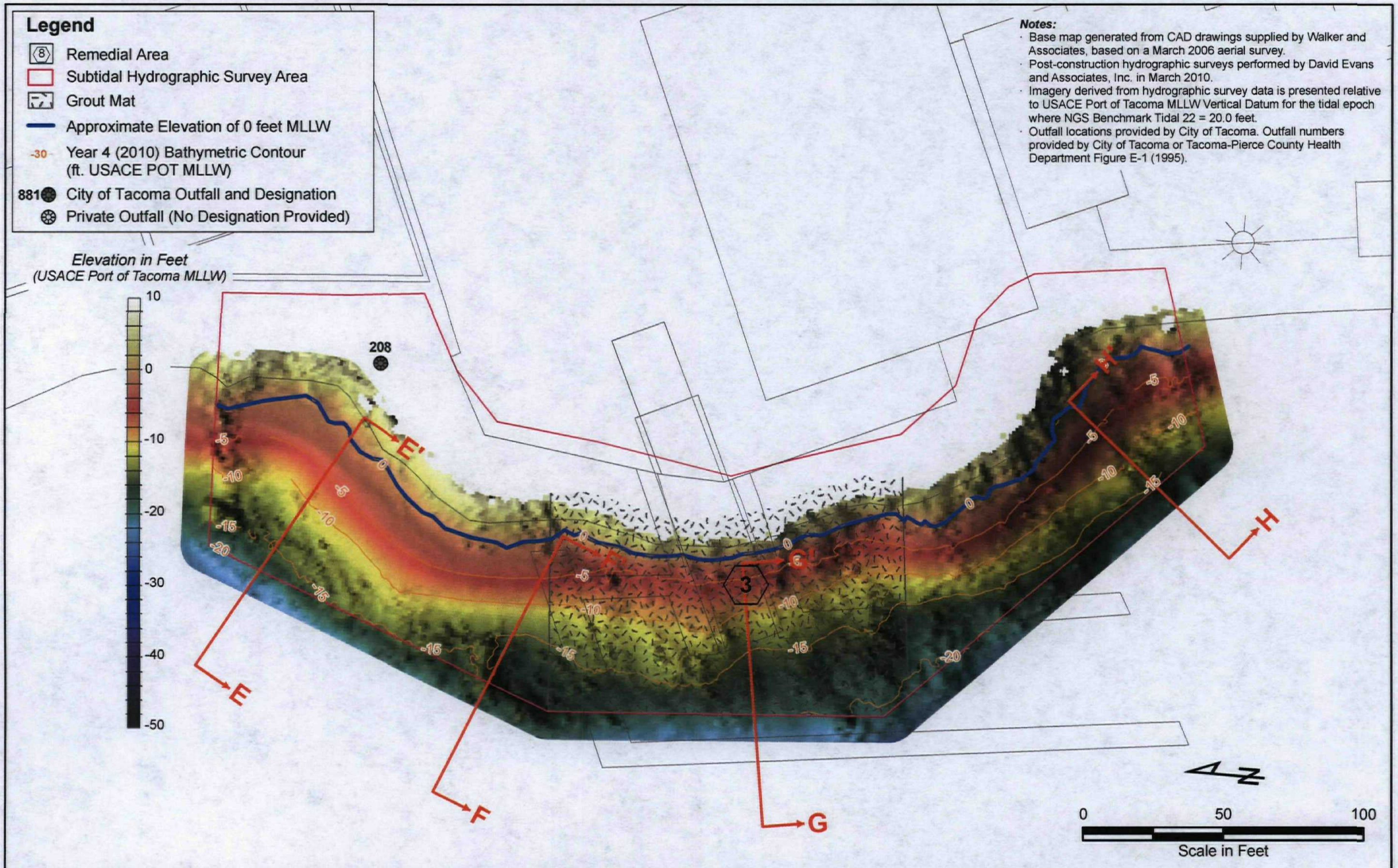

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Figure 27
RA 3 Year 4 (2010) Locations of Bathymetric Cross Sections

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 27 (RA 3 Year 4 (2010) Locations of Bathymetric Cross Sections).mxd
Date: 4/26/2010

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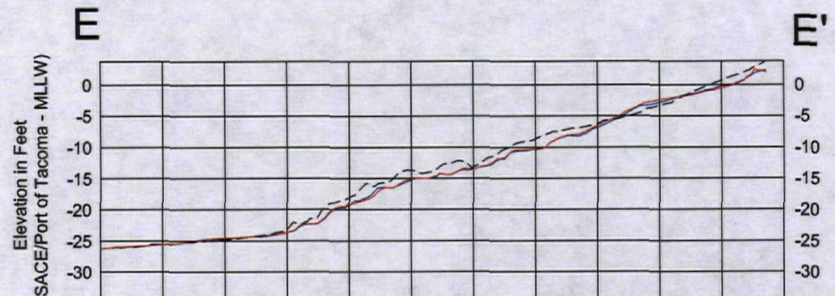
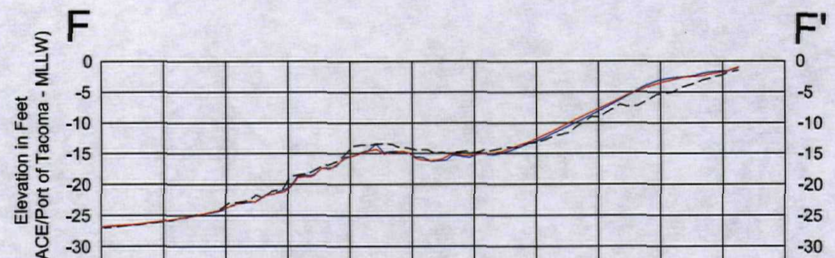
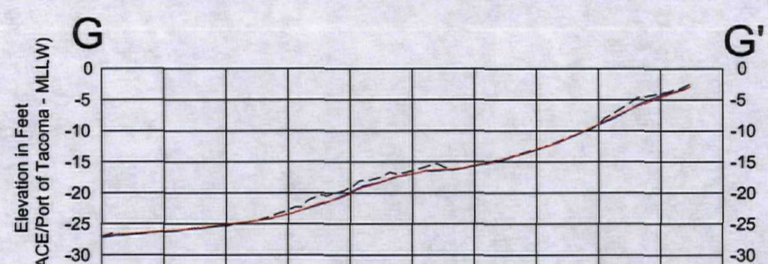


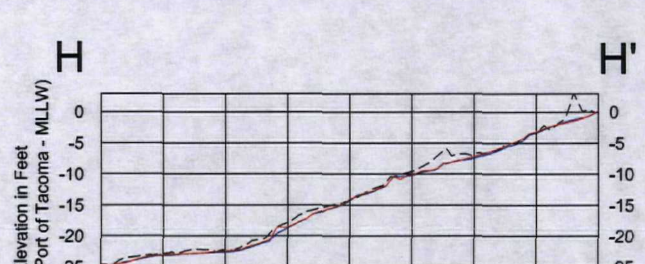
Baseline (2003) SB	-25.5	-24.8	-23.2	-18.0	-13.7	-13.1	-8.7	-6.3	-3.4	0.7	
Year-2 (2008) MB	-25.6	-24.6	-23.7	-19.3	-15.2	-13.4	-10.4	-6.8	-2.8	-0.2	
Year-4 (2010) MB	-25.6	-24.6	-23.7	-19.1	-15.2	-13.5	-10.3	-6.6	-2.5	-0.5	
Change in Elev (Baseline to Y4)	-0.1	+0.2	-0.5	-1.1	-1.5	-0.4	-1.6	-0.3	+0.9	-1.2	
Change in Elev (Y2 to Y4)	0	0	0	+0.2	0	-0.1	+0.1	+0.2	+0.3	-0.3	
	0+10.00	0+20.00	0+30.00	0+40.00	0+50.00	0+60.00	0+70.00	0+80.00	0+90.00	1+00.00	1+10.00



Baseline (2003) SB	-26.0	-23.4	-19.3	-14.3	-14.3	-14.9	-13.2	-9.0	-5.4	-2.2	
Year-2 (2008) MB	-25.9	-23.9	-20.6	-15.5	-15.3	-15.3	-13.0	-8.1	-3.1	-1.6	
Year-4 (2010) MB	-25.9	-23.8	-20.7	-15.5	-15.4	-15.3	-12.6	-7.7	-3.5	-1.8	
Change in Elev (Baseline to Y4)	+0.1	-0.4	-1.4	-1.2	-1.1	-0.4	+0.6	+1.3	+1.9	+0.4	
Change in Elev (Y2 to Y4)	0	+0.1	-0.1	0	-0.1	0	+0.4	+0.4	-0.4	-0.2	
	0+10.00	0+20.00	0+30.00	0+40.00	0+50.00	0+60.00	0+70.00	0+80.00	0+90.00	1+00.00	



Baseline (2003) SB	-26.3	-25.3	-22.8	-19.1	-16.4	-15.6	-13.0	-9.0	-4.1	
Year-2 (2008) MB	-26.2	-25.2	-23.4	-19.8	-16.9	-15.7	-13.0	-9.0	-4.4	
Year-4 (2010) MB	-26.1	-25.1	-23.4	-20.0	-16.9	-15.6	-12.9	-8.9	-4.6	
Change in Elev (Baseline to Y4)	+0.2	+0.2	-0.6	-0.9	-0.5	0	+0.1	+0.1	-0.5	
Change in Elev (Y2 to Y4)	+0.1	+0.1	0	-0.2	0	+0.1	+0.1	+0.1	-0.2	
	0+10.00	0+20.00	0+30.00	0+40.00	0+50.00	0+60.00	0+70.00	0+80.00	0+90.00	1+00.00



Baseline (2003) SB	-22.8	-22.3	-17.8	-14.1	-9.5	-6.9	-3.3	
Year-2 (2008) MB	-23.1	-22.6	-18.7	-14.2	-10.2	-7.4	-3.2	
Year-4 (2010) MB	-23.0	-22.5	-18.4	-14.0	-10.1	-7.2	-3.1	
Change in Elev (Baseline to Y4)	-0.2	-0.2	-0.6	+0.1	-0.6	-0.3	+0.2	
Change in Elev (Y2 to Y4)	+0.1	+0.1	+0.3	+0.2	+0.1	+0.2	+0.1	
	0+10.00	0+20.00	0+30.00	0+40.00	0+50.00	0+60.00	0+70.00	0+80.00

NOTES:

1. Baseline (2003) Single Beam Survey performed by Parametrix. (Feb., 2003)
2. Year 2 (2008) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2008)
3. Year 4 (2010) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2010)
4. Contours and imagery derived from bathymetric data are presented in units of feet relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.

0 30 60
Scale in Feet

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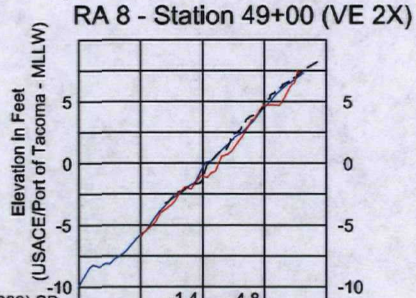
Figure 28
RA 3 Comparison of Year 4 to Baseline and Year 2 Subtidal Hydrographic Capped Area Cross Sections

I I'

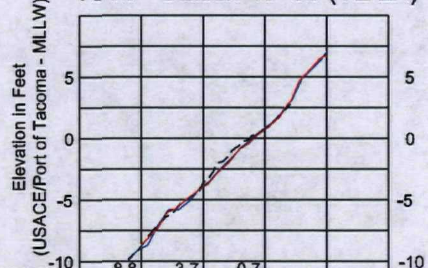
RA 8 - Station 49+00 (VE 2X)



	8+90	9+00	9+10
Baseline (2003) SB		-1.4	4.8
Year-2 (2008) MB		-0.4	4.5
Year-4 (2010) MB		-1.1	4.6
Change in Elev (Baseline to Y4)		+0.3	-0.2
Change in Elev (Y2 to Y4)		-0.7	+0.1

J J'

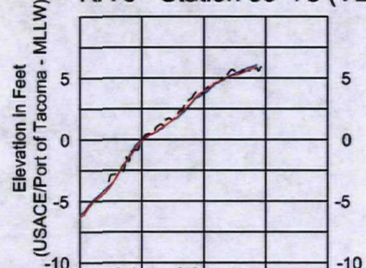
RA 8 - Station 49+50 (VE 2X)



	8+80	8+90	9+00	9+10
Baseline (2003) SB	-8.8	-3.7	0.7	
Year-2 (2008) MB	-8.9	-3.9	0.8	
Year-4 (2010) MB	-8.7	-4.0	0.7	
Change in Elev (Baseline to Y4)	+0.1	-0.3	0	
Change in Elev (Y2 to Y4)	+0.2	-0.1	-0.1	

K K'

RA 8 - Station 50+75 (VE 2X)



	8+80	8+90
Baseline (2003) SB	-0.1	3.8
Year-2 (2008) MB	0.0	3.7
Year-4 (2010) MB	-0.2	3.9
Change in Elev (Baseline to Y4)	-0.1	+0.1
Change in Elev (Y2 to Y4)	-0.2	+0.2

NOTES:

1. Baseline single beam transects performed by Manson following construction completion (2005/2006).
2. Year 2 (2008) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2008)
3. Year 4 (2010) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2010)
4. Contours and imagery derived from bathymetric data are presented in units of feet relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.
5. VE - vertical exaggeration of profile

Horizontal Scale in Feet
0 30 60
0 15 30
Vertical Exaggeration Scale in Feet

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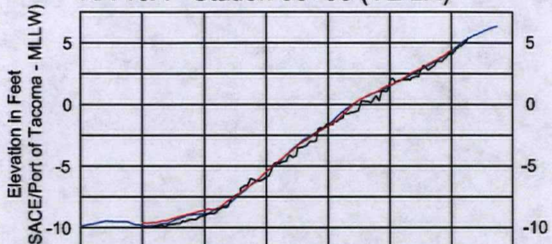
Figure 29
RA 8 Comparison of Year 4
to Baseline and Year 2
Bathymetric Cross Sections

L — L'

RA 19A - Station 56+00 (VE 2X)



	8+20	8+30	8+40	8+50	8+60	8+70
Baseline (2003) SB		-9.1	-5.9	-1.6	1.8	4.1
Year-2 (2008) MB		-8.9	-5.5	-1.6	1.5	4.3
Year-4 (2010) MB		-8.6	-5.5	-1.8	1.5	4.4
Change in Elev (Baseline to Y4)		+0.5	+0.4	-0.2	-0.3	+0.3
Change in Elev (Y2 to Y4)		+0.3	0	-0.2	0	+0.1

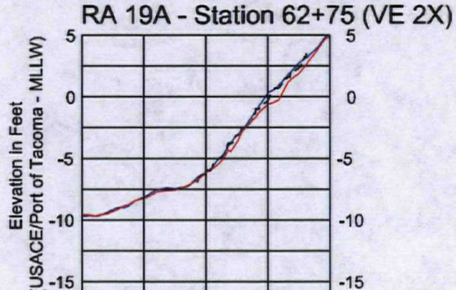
M — M'

RA 19A - Station 57+00 (VE 2X)

	8+20	8+30	8+40	8+50	8+60	8+70
Baseline (2003) SB	-10	-7.9	-5.9	-1.0	2.8	3.5
Year-2 (2008) MB	-9.5	-9.2	-5.8	-1.5	1.7	3.3
Year-4 (2010) MB	-9.4	-9.0	-5.8	-1.7	1.9	3.3
Change in Elev (Baseline to Y4)	+0.6	-1.1	+0.1	-0.7	-0.9	-0.2
Change in Elev (Y2 to Y4)	+0.1	+0.2	0	-0.2	+0.2	0

N — N'

RA 19A - Station 62+75 (VE 2X)



	8+70	8+80	8+90	9+00
Baseline (2003) SB		-6.0	-0.3	
Year-2 (2008) MB		-6.1	0.2	
Year-4 (2010) MB		-6.2	-0.7	
Change in Elev (Baseline to Y4)		-0.2	-0.4	
Change in Elev (Y2 to Y4)		-0.1	-0.9	

NOTES:

1. Baseline single beam transects performed by Manson following construction completion (2005/2006).
2. Year 2 (2008) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2008)
3. Year 4 (2010) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2010)
4. Contours and imagery derived from bathymetric data are presented in units of feet relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.
5. VE - vertical exaggeration of profile

Horizontal Scale in Feet
0 30 60
0 15 30
Vertical Exaggeration Scale in Feet

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Figure 30
RA 19A Comparison of Year 4 to Baseline and Year 2 Bathymetric Cross Sections

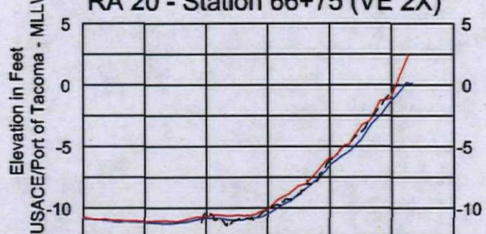
O O'

RA 19B - Station 68+50 (VE 2X)

	7+90	8+00	8+10	8+20	8+30	8+40
Baseline (2003) SB	-12.5	-12.1	-8.3	-3.6	1.2	
Year-2 (2008) MB	-12.3	-11.9	-8.7	-4.6	1.0	
Year-4 (2010) MB	-12.3	-11.8	-8.8	-4.9	1.0	
Change in Elev (Baseline to Y4)	+0.2	+0.3	-0.5	-1.3	-0.2	
Change in Elev (Y2 to Y4)	0	+0.1	-0.1	-0.3	0	

P P'

RA 20 - Station 66+75 (VE 2X)



		4+30	4+20	4+10	4+00	3+90
Baseline (2003) SB			-10.4	-10.2	-6.1	-0.5
Year-2 (2008) MB			-10.8	-10.4	-6.5	-1.2
Year-4 (2010) MB			-10.7	-10.0	-5.9	-0.7
Change in Elev (Baseline to Y4)			-0.3	+0.2	+0.2	-0.2
Change in Elev (Y2 to Y4)			+0.1	+0.4	+0.6	+0.5

Q Q'

RA 20 - Station 68+50 (VE 1X)

	5+70	5+60	5+50	5+40	5+30	5+20
Baseline (2003) SB		-11.0	-7.4	-4.8	0.1	
Year-2 (2008) MB		-10.6	-8.0	-5.0	-1.0	
Year-4 (2010) MB		-10.5	-8.1	-5.1	-1.0	
Change in Elev (Baseline to Y4)		+0.5	-0.7	-0.3	-1.1	
Change in Elev (Y2 to Y4)		+0.1	-0.1	-0.1	0	

NOTES:

1. Baseline single beam transects performed by Manson following construction completion (2005/2006).
2. Year 2 (2008) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2008)
3. Year 4 (2010) Multibeam Survey performed by David Evans and Associates, Inc. (March, 2010)
4. Contours and imagery derived from bathymetric data are presented in units of feet relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.
5. VE - vertical exaggeration of profile

Horizontal Scale in Feet
0 30 60
0 15 30
Vertical Exaggeration Scale in Feet

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Figure 31
RA 19B and RA 20 Comparison of Year 4 to Baseline and Year 2 Bathymetric Cross Sections

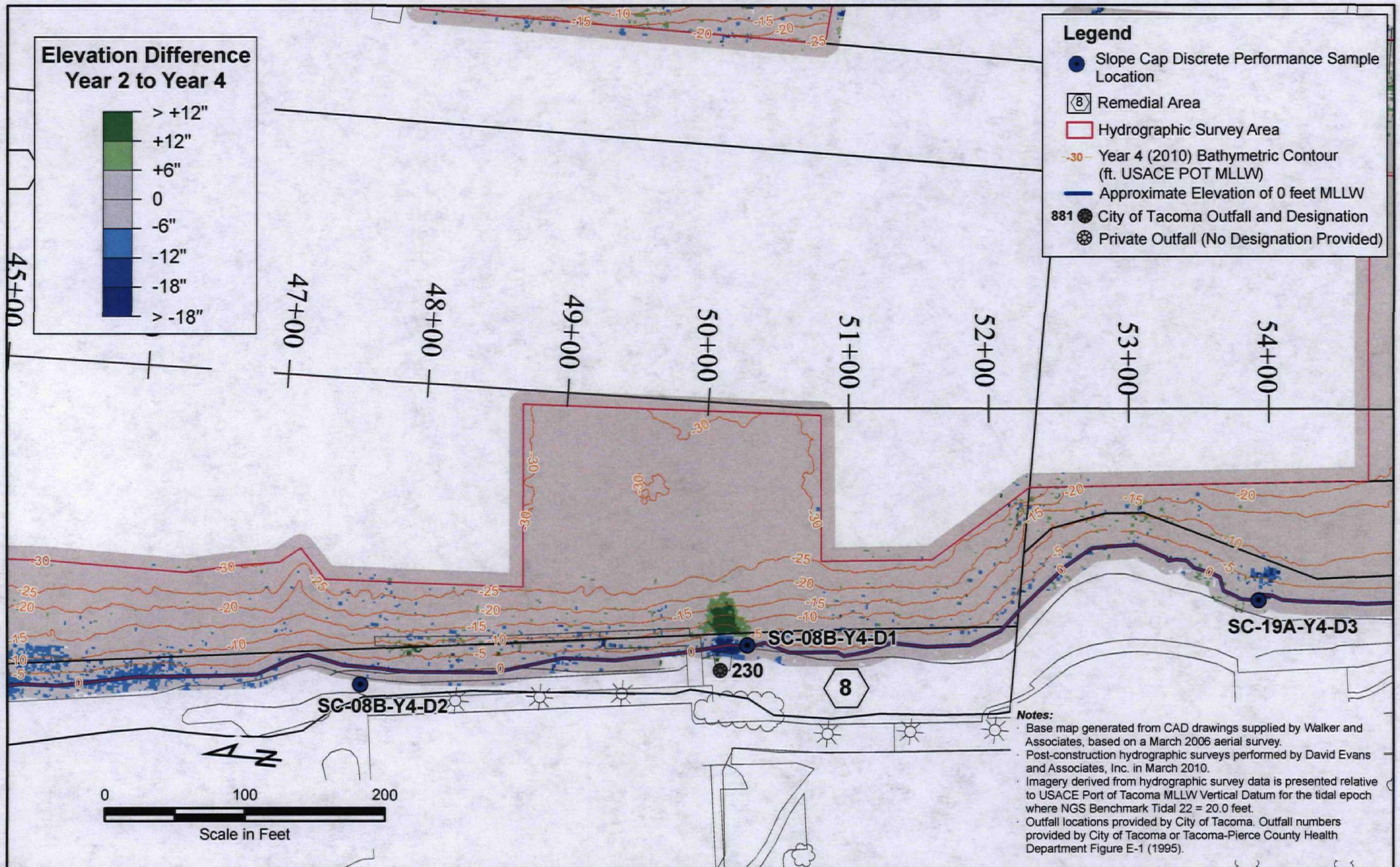

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Figure 32
RA 8 - Location of Slope Cap Discrete Performance Samples

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 32 (RA 8 Location of Slope Cap Discrete Preformance Sample).mxd
Date: 5/14/2010

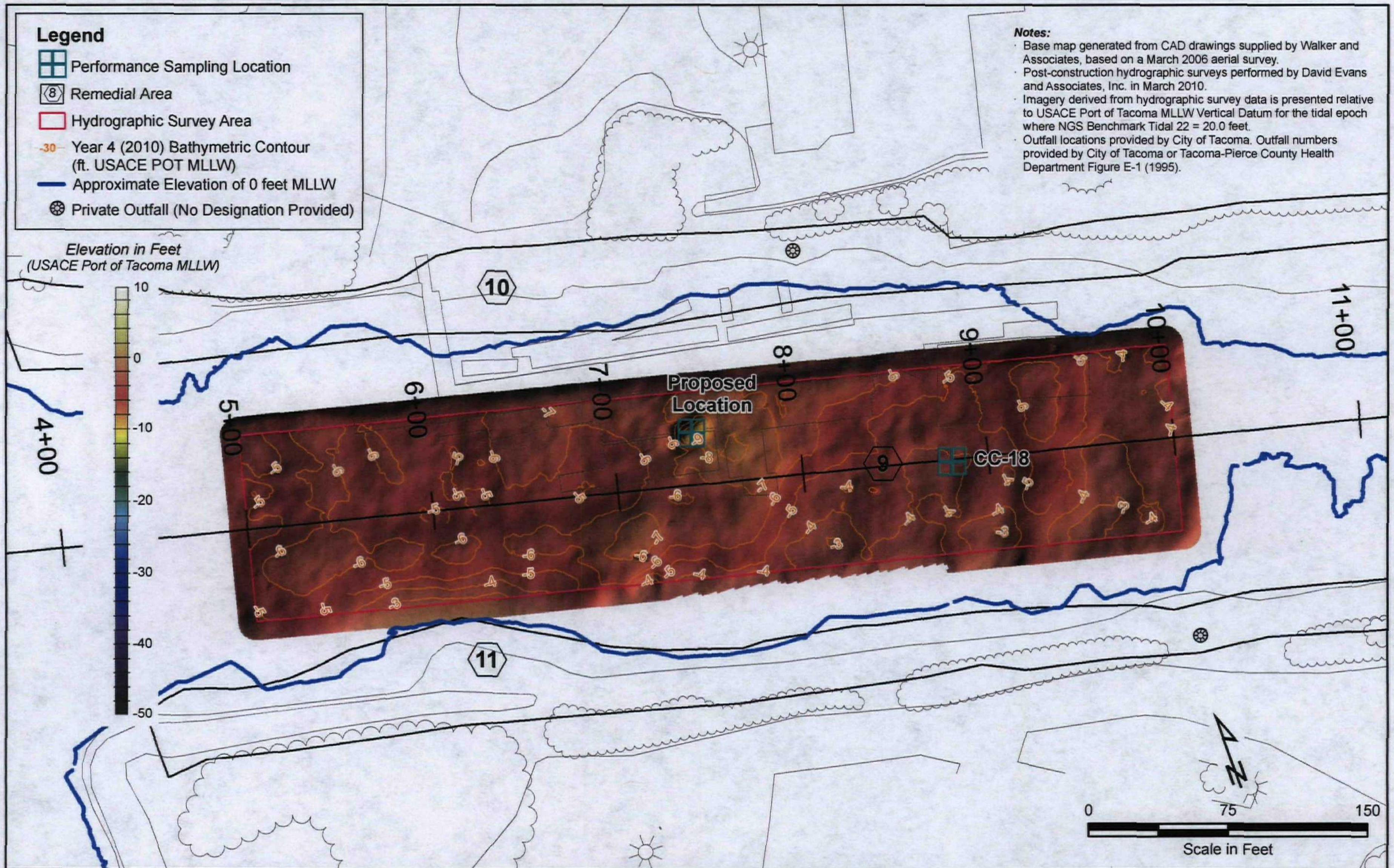

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Figure 33
RA 9 Scour Depression and Proposed Additional Performance Sampling Location

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure 33 (RA 9 Scour Depression and Proposed Additional Sampling Location).mxd
Date: 5/14/2010

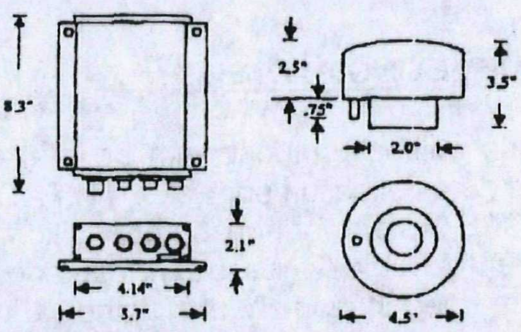
ATTACHMENT A

- SPECIFICATIONS FOR THE BASELINE (2003) SINGLE BEAM EQUIPMENT
- HYDROGRAPHIC SURVEY CONTRACTOR REPORT – BASELINE (2005/2006) SURVEY EQUIPMENT AND PROCEDURES
- HYDROGRAPHIC SURVEY CONTRACTOR REPORT – YEAR 2 (2008) SURVEY EQUIPMENT AND PROCEDURES
- HYDROGRAPHIC SURVEY COMPARISON (2006 MULTIBEAM TO 2008 MULTIBEAM) MEMORANDUM

HYDROGRAPHIC SURVEYING SYSTEM

The Manson Construction Co. survey boat "Bub" will be equipped with Coastal Oceanographics' HYPACK MAX hydrographic data collection software. HYPACK MAX integrates a Starlink DNAV212G Differential GPS system for horizontal positioning, an INNERSPACE 448 single frequency fathometer for vertical measurements, and a Hazen Tide Gauge for tidal adjustments. Attached are specification sheets for the various electronic components.

Hydrographic surveys are performed according to the standards of the U.S. Army Corps of Engineers. Field notes will include the file name for each survey line, with the corresponding time, tide reading, and number of satellites being received by the Starlink at the beginning of each line. Any line terminated early will be given explanation. Speed of sound tests and verification of tidal data will be recorded for each survey. Data will be processed using HYPACK MAX software to produce cross sections including template design and survey data. Any volume calculations will be performed using Standard Hypack method.



DNAV-212G Combined DGPS Sensor

Specifications

GPS RECEIVER

ACCURACY, DYNAMIC OR STATIC

Horizontal	
CEP (50%)	40 cm
RMS (67%)	70 cm
2DRMS (95%)	< 1 m
Vertical	
2DRMS (95%)	< 2 m

SIGNAL PROCESSING

Number of Channels:	12
Tracking:	C/A (L1) code, smoothed with "All in View" operation
Update Rate:	10 per second
Reacquisition:	2 seconds
Speed (Max):	1000 Knots
Altitude (Max):	60,000 Feet

TIME TO FIRST FIX

Cold Start:	90 seconds
Warm Start:	10 seconds

CONTROL INTERFACE

Main (Port A):	RS232, 300 to 115K bps using NMEA format data
Aux (Port B): (external option)	RS-232, 300 to 9600 bps, using RTCM SC104

MBA-2 GPS/BEACON ANTENNA

GPS ANTENNA

Type:	Patch
Bandpass:	1575 MHz ± 2 MHz
Gain:	30 db
Axial Ratio:	3 db Max
Noise Figure:	2.5 db Max

BEACON ANTENNA

Type:	"H" field, magnetic loop
Bandpass:	283.5 to 325 KHz ± 1 db
Gain vs. Azimuth:	Omni, ± 1 db
Sensitivity:	-12 db uV/(meters · Hz$^{1/2}$)

RADIOBEACON RECEIVER

SIGNAL PROCESSING

Number of Channels:	2 + 1 for impulse detection
Frequency Range:	283.5-325.0 KHz
Timing Resolution:	< 1 Hz
Minimum Signal:	< 5uV/m @ 100 bps
Dynamic Range:	100 db
Adjacent Channel Rejection:	> 50 db @ 1KHz

RADIOBEACON RECEIVER (Continued)

SIGNAL PROCESSING

Acquisition Time	
Manual Mode:	5 seconds
Automatic Warm Start:	15 seconds
Automatic Cold Start:	15 minutes max.
Noise Blanker:	Predictive variable length using a third AGC (automatic gain control) channel for detection
Signal Detection:	Acquisition via FLL (frequency locked loop)

COMBINED SPECIFICATIONS

ENVIRONMENTAL

Operating Temperature	
Receiver:	-30 to +70°C
Antenna:	-40 to +70°C
Relative Humidity	
Receiver:	100%
Antenna:	100%
Receiver and Antenna are waterproof	

SIZE AND WEIGHT

Receiver:	2.1"h x 5.7"w x 8.3"d
Weight:	< 3 pounds
Antenna:	3.5"h by 4.5" diameter
Weight:	< 1.3 pounds

POWER REQUIREMENTS

Input Voltage:	11 to 32 VDC
Power Consumption:	< 6 Watts @ 12 VDC

CONNECTIONS

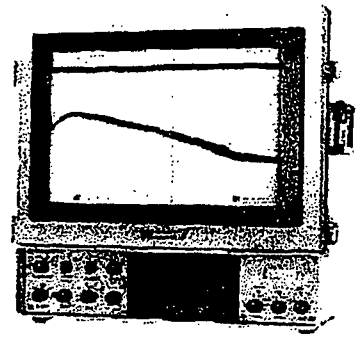
Antenna:	Waterproof TNC
Receiver:	All Waterproof

STARLINK

Starlink Incorporated
6400 Highway 290 East, Suite 202
Austin, Texas 78723 U.S.A.
Phone: (512) 454-5511 · (800) 460-2167
Fax: (512) 454-5570
E-mail: dnav212g@starlinkdgps.com
Internet: www.starlinkdgps.com

Model 448 Thermal Depth Sounder Recorder

Manufacturer: INNERSPACE TECHNOLOGY, INC.



The Innerspace Technology Model 448 Thermal Depth Sounder Recorder provides survey precision, high resolution depth recordings using SOLID STATE THERMAL PRINTING. The lightweight, portable unit is designed for use in small boat surveying.

The Model 448 TDSR uses a thermal printing technique pioneered by Innerspace for depth sounding which provides the high resolution and accuracy. The state of the art design allows integration into portable hydrographic survey systems.

Operation

The Model 448 TDSR utilises the highest resolution, solid state, fixed thermal print head available for depth sounding. Blank white, high contrast thermal paper is used to print the selected range scale along with the depth. The depth is always read directly from the scale printed, thereby avoiding the possible confusion encountered when examining outmoded, pre-printed, multi-scaled charts. Built-in chart annotation is standard and includes printing of numerical values for Speed of Sound, Tide and Draft. Time and event marks are numerically annotated and the chart is automatically labelled FEET or METERS as determined by the MODE switch.

Operator controls are provided on a gasketed, splashproof front panel. Thumbwheel switch settings are behind a splashproof access cover on the front panel, and the digitiser controls and display are provided on a front panel plug in module.

The microprocessor controlled sounder/recorder utilises plug in printed circuit boards, a modular plug in power supply and plug in modular digitiser. Minimum wiring connections help provide an extremely reliable and serviceable unit. A pre-programmed test routine and diagnostic LED indicators provide valuable assistance for the operator and/or electronics technician.

The single package portable unit may be used vertically or horizontally and can be powered from either an AC or DC source.

Features

- LARGE VIEWING area with sliding window
- BLANK PAPER is high contrast black on white and low in cost
- PORTABLE and lightweight for small boat operation
- FEET or METERS operation - switch selectable
- THUMBWHEEL SETTINGS for speed of sound, tide and draft
- ANNOTATION of all parameters appear on recordings in chart margin Speed of Sound, Tide, Draft, Event, Time and Mode of Operation
- TVG (time varied gain) minimises gain adjustments
- INTERNAL micro controlled depth digitiser
- NO ADJUSTMENTS for zero line or call line are required

Options

- CUSTOM LOGO : Programmes recorder to repetitively print, in the lower chart margin, customer specified information such as user's logo, name, address, etc.

- FREQUENCY : Choice of either 208 kHz or 125 kHz
- POWER : Allows operation from either 110/120, 220/240 VAC or (not including) 12, 24 VDC

Specifications

MODEL 448 Single Frequency TDSR

- PRINTING : Thermal solid state fixed head thick film
- CHART PAPER : 8.75 inches x 200 feet
- PAPER SPEEDS : 0.5,1,2,4 or 8 inches/min. (Depends on scale selected)
- DEPTH RANGES : 0 to 335 feet or 0 to 80 metres. 6 overlapping phases of 60 feet or 15 metres

- A x 2 SWITCH multiplies each range by a factor of 2
- A x .5 SWITCH multiplies each range by a factor of 0.5
- ACCURACY : ±0.1 foot or metre timing and printing resolution
- SPEED OF SOUND : Thumbwheel switch selectable 4550 to 5050 feet/sec. or 1350 to 1550 metres/sec. Precision crystal referenced frequency synthesiser using a phase locked loop provides exact calibration
- TIDE : Thumbwheel switch selectable from 0 to ± 25.0 feet or metres
- DRAFT : Thumbwheel switch selectable from 0 to + 99.9 feet or metres
- EVENT MARK : Front panel switch or remote, increments internal counter
- TIME : Internal clock with battery backup
- SOUNDER FREQUENCY : 208 kHz or 125 kHz standard or others optional
- TRANSDUCERS

- 208 kHz 8 degree beamwidth at - 3db
- 208 kHz 3 degree beamwidth at - 3db (optional)
- 125 kHz 14 degree beamwidth at - 3db (optional)
- PULSE LENGTH : 0.15 to 0.6 ms. Automatically determined by frequency and depth range selected
- PULSE POWER : 250 watts RMS
- SOUNDING RATE : 1,200 soundings per minute maximum
- TIME VARIED GAIN (TVG) : Automatically compensates for spreading loss and attenuation over depth range
- GAIN CONTROL : Provides manual gain adjustment
- STANDBY MODE : Allows transceiver and digitiser (if used) to operate without running chart paper
- OUT OF PAPER : Indicated by blinking front panel light. Paper motion stops, but sounding SENSOR continues.
- RAPID PAPER ADVANCE : Front panel switch allows for the rapid advance of blank paper
- ANNOTATION : The numerical value of Speed of Sound, Tide, Draft, Time and Event are permanently recorded above the chart record periodically
- DIGITISER : In addition to the built in depth digitiser, Start/Stop pulses are available for OUTPUT use external digitisers such as Innerspace Models 410, 412 and 445
- POWER : Either 12, 24 V DC or 120, 240 V AC (Must be specified AC or DC)
- DIMENSIONS : 17 in. W x 17.25 in. H x 9.25 in. D
- WEIGHT : 45 pounds
- ENCLOSURE : Coated aluminium, corrosion resistant and splashproof. Sliding window for chart access and settings door for easy access to thumbwheel switches.

Internal Microprocessor Digitiser

- OPERATING MODES : Either a DIRECT, GATED, AUTO or MANUAL mode may be chosen

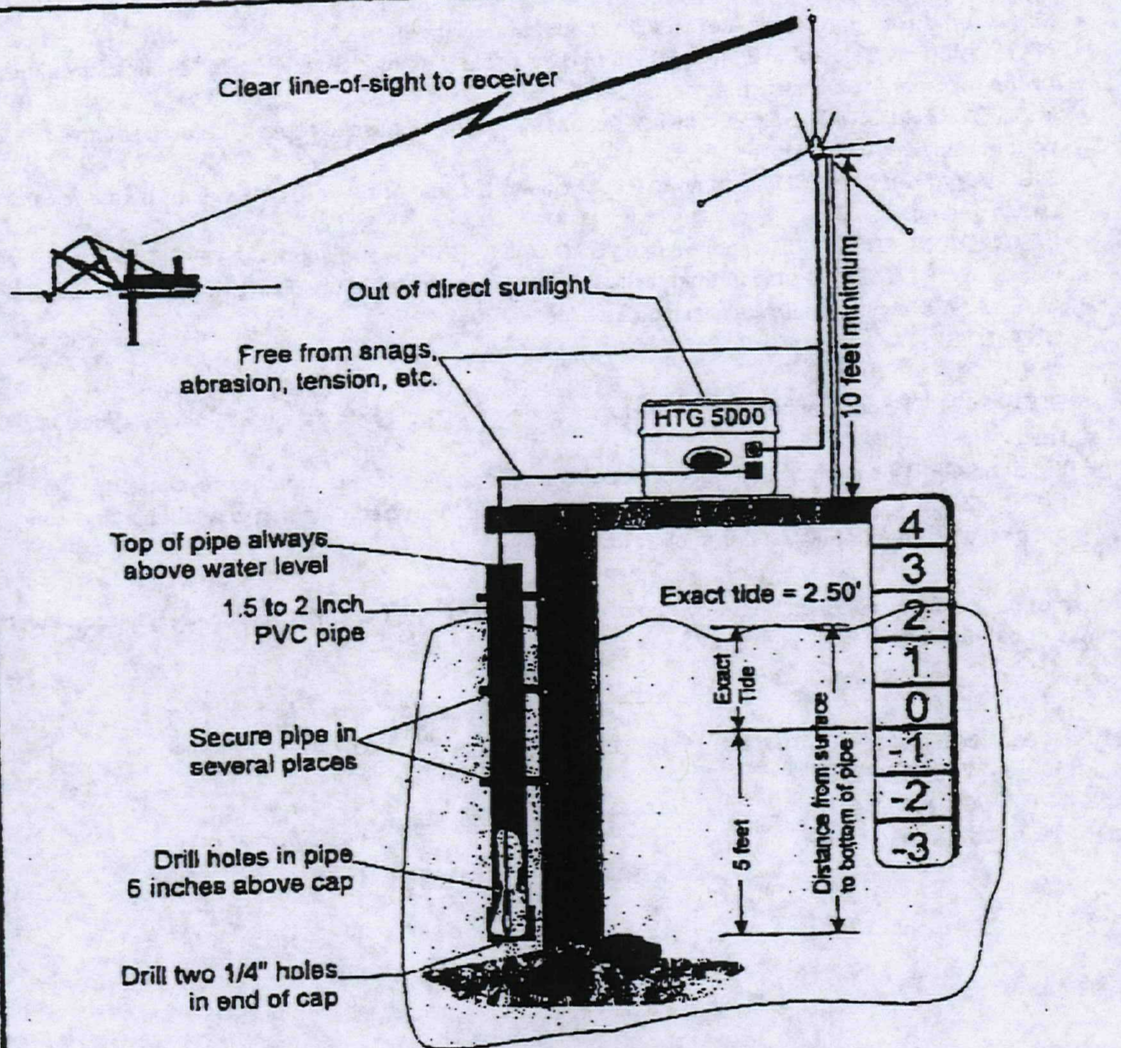
- DIRECT - No gate present.
- GATED - Gate width doubles, then quadruples automatically to re-acquire the bottom reply
- AUTO - Gate width doubles, quadruples then goes to non-gated automatically to re-acquire the bottom reply
- MANUAL - Fixed gate as pre-set on initial depth thumbwheel
- GATE WIDTH : Selectable 2, 4, 8, 20, 40 or 80 via rotary switch. Gate width in feet or metres, determined by the recorder MODE switch setting
- MISSED REPLIES - The REPLY switch selects 2, 4, 8 or 16 missed replies, before reacquisition of bottom reply, in AUTO mode
- DISPLAY : Four digit LCD 7 segment. Resolution to 0.1 feet or metres, determined by the recorder switch setting
- INDICATORS : Three LED's representing BAD DATA, REPLY and depth GATE
- INITIAL DEPTH : Three station thumbwheel switch allows entry of an initial depth gate position
- ALARM : A switched audible alarm indicates loss of track
- OUTPUTS :

- BCD - 8421 TTL compatible 5V positive logic. Buffered outputs with data hold, inhibit, strobe and flag lines
- IEEE488 GPIB - 4 digits with proper protocol and selectable address switches (optional)
- EIA RS232C - 4 digits with selectable baud rates (optional). A bad data flag is available and can optionally set the output number to all zeros

Because of our desire to continually improve products and equipment, design and specification are subject to change without notice.

Del Norte Technology Limited
Telephone: +44 (0)1793 827982
Fax: +44 (0)1793 827984
e-mail: mail@del-norte.co.uk

MODEL HTG5000 TRANSMITTER INSTALLATION GUIDE



CALIBRATION PROCEDURE

1. Accurately detemine the exact 0 tide level reading at the installation site.
2. Position the bottom of the stilling pipe five feet below this tide reading. In the example above, the bottom of the pipe would be 7.5 feet below the surface.
3. Make certain that the top of the stilling pipe will always be above the water surface.
4. Lower the transducer to the bottom of the stilling pipe, making certain that the cable is free from snagging abrasion, tension, etc.
5. With the internal switch set on T, adjust the **CAL** knob until the receiver displays the exact tide (e.g., 2.50').

SPECIFICATIONS

TRANSMITTER SPECIFICATIONS

OUTPUT POWER	2 WATTS NOMINAL OUTPUT, VHF OR UHF TYPE ACCEPTED UNDER FCC PARTS 21, 81, 89, 91, 93 AND 95A.
MODULATION FREQUENCY ACCURACY CIRCUITRY	BINARY CODED AUDIO FSK +/- 0.0005% (-30 TO +60 DEG C) MICROPROCESSOR CONTROLLED
TRANSMIT TIME	APPROX. ONE SECOND
REPEAT INTERVALS	9 SEC, 5, 10, 20 MINUTES
BATTERY LIFE	4 WEEKS TO 7 MONTHS DEPENDING UPON REPEAT INTERVAL, BATTERY CHARGING AND TEMPERATURE.
TIDE RESOLUTION	+/- 0.01 FT
SENSOR	QUARTZ STRAIN GAUGE BRIDGE, HOUSED IN TITANIUM BODY WITH POLYURETHANE SHEATHED CABLE.
POWER CONSUMPTION	12VDC, 110 MICROAMPERES STANDBY. 400 MILLIAMPERES OPERATING.
ADJUSTMENTS	SINGLE CONTROL TIDE CALIBRATION.
SIZE	7.5H X 11.5W X 13D (INCHES)
WEIGHT	8.5 LBS

DAVID EVANS AND ASSOCIATES INC.

MEMORANDUM

Date: May 01, 2008
Client: Floyd | Snider
Subject: Thea Foss and Wheeler Osgood Waterways Remediation Project
Post - Construction Hydrographic Survey (2006)
Summary of Survey Procedures and Equipment

Project Parameters
Horizontal Datum: *NAD 83/91*
Vertical Datum: *Project Datum (Tidal 22 = 20.0')*
Coordinate System: *Washington State Plane – South Zone*
Units: *US Survey Feet*

Survey Dates
December 21 & 22, 2005. Additional survey on February 12, 2006.

Survey Crew
December 2005
Ben Hocker – Senior Hydrographer
Travis Brennan – Hydrographer III

February 2006
Mike Mutschler – Senior Hydrographer
Travis Brennan – Hydrographer III

Equipment
Vessel – DEA's 33-foot *John B Preston*
Multibeam – Reson 8101 240 kHz, 101 beam, 150° swath with 15° roll bias to starboard.
Motion Sensor – Applanix POS-MV
Heading Sensor – Applanix POS-MV
Positioning – Trimble MS750 RTK GPS rover on vessel with a base station setup on DEA control point # 2019 (North end, west side Thea Foss waterway).
Navigation and data logging – Hypackmax Hysweep Ver 4.3a Gold
Sound Speed - Odom Digibar

Position Check
Each day after base station setup, a confidence check was made on a secondary control point DEA #2016 (North side Wheeler-Osgood near Marine Floats Company) by decoupling the RTK antenna from the vessel, placing it on a fixed length staff and occupying the control point. Values agreed to within 0.1 ft for all components as displayed in the following table.

	Easting (X) US Feet	Northing (Y) US Feet	Elev (Z) FT
Actual DEA 2016	1160938.30	705579.64	16.90
Delta 12/21/05	0.10	0.05	0.05
Delta 12/22/05	0.05	0.05	0.02
Delta 02/12/06	0.08	0.08	0.04

Patch Test

Prior to the start of survey operations, data was collected along a series of controlled transects to be used for checking the alignment and system latency of the survey equipment. After analysis during data processing the following correction values were determined and applied during data processing.

	Roll	Pitch	Yaw	Latency
12/2005	0.61°	1.0°	-0.30°	0.00 sec
02/2006	-0.31°	0.11°	-1.10°	0.00 sec

Sound Velocity Casts

Detailed measurements of the sound velocity profile through the water column are crucial in multibeam surveys. Changes in the velocity profile will not only affect acoustic distance measurements, but can also cause refraction or bending of the sonar path as it passes through layers in the water column with different velocities. An ODOM Digibar Pro was used to measure the speed of sound of the water column during the December 2005 survey work and a Seabird SBE19 was used to acquire sound velocity information in February 2006.

Bar Check and Lead Line Comparison

A flat bar target was held below the multibeam sensor to verify draft adjustments to the system. The bar was held at a measured depth of 6.562 ft (2.0 m) and a sampling of the raw soundings observed in the CARIS processing workstation.

Date	Draft (ft)	Bar Depth (ft)	Obs MB Depth (ft)	Delta (ft)
12/21/05	-0.92	6.562	6.62	0.06
02/12/06	-1.46	6.562	6.51	0.05

Three lead line soundings taken during survey operations in December 2005 compared well to the final post construction multibeam dataset. The closest elevation, from the 1.64 ft (0.5 m) gridded data base to the lead line position, was used as the basis of comparison.

X	Y	Raw Depth	Tide	Corr. Elev	MB Database	Delta (ft)
1161849	705256	11.45	13.1	1.65	1.7	-0.05
1160225	705815	35.5	13.1	-22.4	-22.6	0.2
1160659	702858	24.9	12.8	-12.1	-12.3	0.2

Multibeam Data Acquisition
Soundings were acquired with a Reson SeaBat 8101 multibeam bathymetric sonar using a frequency of 240 kilo hertz (kHz). The system records 101 soundings in a single sonar ping. Additionally, DEA's 8101 includes options such as a stick projector for enhanced shallow water performance and the ability to output side scan sonar imagery. The stick projector option on the Reson SeaBat 8101 improves the system performance in shallow water (depths less than 150 ft).

Multibeam data was conducted by running lines both parallel and perpendicular with the waterway for the length of the project. In many areas, obstructions from construction activities prevented the vessel from surveying close to the shoreline. Several areas were inaccessible or blocked by large vessels, floats or obstructions. For this survey, the sonar head was mounted with 15-degree starboard angle to allow for maximum coverage of side slope areas. This enabled coverage over a range of 90° from nadir (straight down) to starboard and 60° from nadir to port with a recorded depth every 1.5°.

The accepted angles were opened up along the slopes and to reach under obstructions. The total swath width of full coverage mapping in a single pass varied with the water depth.

The most vital measurements in a multibeam survey are heading and roll angles. To account for vessel heading, heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor was utilized. By utilizing vessel speed over ground and heading data provided by GPS, the POS/MV can isolate horizontal accelerations from vessel turns and provide highly accurate motion data. The POS/MV system was also used to record vessel heading (yaw) from which the sonar beam orientation was derived. The POS/MV provides a higher degree of accuracy for heading measurements than a conventional gyrocompass.

The navigation and survey control system was a personal computer running Hypack MAX software. Hypack Hysweep software was used for multibeam and sensor data acquisition. Hypack MAX software allowed the swath bathymetric data to be displayed as a painted color image in a "matrix" on the navigation screen. The matrix cell size on was set to 3.28 ft during operations. This real-time display gave the hydrographers immediate indications of data quality and coverage.

Processing Procedures

Tides
The elevation data obtained from the RTK GPS system was stripped out and averaged at a 10-sec sliding window. In addition, tide data from the NOAA gauge in Tacoma (9446484) was downloaded for the survey period for comparison.

Data Editing
Post-processing of multibeam data was conducted utilizing Caris HIPS multibeam analysis and processing software version 6.1/SP1/HF 7. Patch test data was analyzed and alignment corrections were applied. Water-level data was applied to adjust all depth measurements to

project datum from the RTK GPS processed data. Velocity profiles were used to correct slant range measurements and compensate for any ray path bending.

Processing began with review of each survey line using Caris swath editor. Verified water surface correctors were applied to the data set at this time. Position and sensor data was reviewed and accepted. Sounding data was reviewed and edited for data flyers. Sounding data, including sonar beams reflecting from sediment in the water column or noise in the water column, were carefully reviewed before flagged as rejected. In each case, data was not eliminated and can be re-accepted in the future if required. Also during editing, real features not associated with bottom elevations but of possible interest, pilings and bridge footings, etc., were designated as examined. This designation allows these features to be included in the hillshade images which add references points to aid in interpretation. The "examined" soundings were not included in the final data exported for difference modeling or contouring.

After swath editing, all data was reviewed through the Caris HIPS subset editing program to ensure no flyers remained in the data set, or to re-accept data previously flagged in the swath editor. In the Caris subset editor, a set of lines was reviewed together for line to line comparison to ensure agreement to one another in a Caris session.

Data Export

To take advantage of the level of detail the multibeam bathymetric survey provided for the waterway, a 0.5-meter grid of the survey area was created by the HIPS processing software and exported to an ASCII XYZ file. This process created a 0.5-meter grid over the survey coverage area and then assigned values to each grid node with an inverse distance weighted algorithm. The ASCII XYZ points file uses the North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS), Washington South Zone with units in US Survey feet.

Data Images

The 0.5-meter database was rendered in CARIS to produce a hillshade image of the bottom bathymetry. The hillshade image is a colored rendering of the surface with shadows created by a artificial sun to help draw out features and make the image more interpretable. For the Thea-Foss waterway a 3x3 interpolation was applied to the 0.5-meter surface to reduce the distracting effects of empty pixels. The interpolation was only applied to the hillshade image and not to any other products. The parameters used for creating the hillshade image were:

Sun Azimuth	Sun Elevation	Vertical Exaggeration
115°	45°	2X

Data Contours

The exported soundings from the 2006 multibeam survey were imported in to Trimble Terramodel software for generation of 1-foot elevation contours. The contours were exported in AutoCAD DXF files for use in producing the final deliverable drawings delivered to Manson Construction in June 2006.

DAVID EVANS AND ASSOCIATES INC.

MEMORANDUM

Date: May 01, 2008
Client: Floyd | Snider
Subject: Thea Foss and Wheeler Osgood Waterways Remediation Project
Year 2 (2008) Subtidal Cap Monitoring Hydrographic Survey
Summary of Survey Procedures and Equipment

Project Parameters
Horizontal Datum: *NAD 83/91*
Vertical Datum: *Project Datum (Tidal 22 = 20.0')*
Coordinate System: *Washington State Plane – South Zone*
Units: *US Survey Feet*

Survey Dates
March 5 & 6, 2008. Additional QC checks were obtained on March 7, 2008

Survey Crew
Greg Baird – Senior Hydrographer, ACSM* Hydrographer, OR PLS
Travis Brennan – Hydrographer III
Nicholas Lesnikowski – Lead Hydrographer, Project Manager, ACSM* Hydrographer
Client representatives Iain Wingard and Nick Bacher were on board through significant portions of survey operations.

Equipment
Vessel – DEA's 33-foot *John B Preston*
Multibeam – Reson 8101 240 kHz, 101 beam, 150° swath with 15° roll bias to starboard.
Motion Sensor – Applanix POS-MV
Heading Sensor – Applanix POS-MV
Positioning – Trimble MS750 RTK GPS rover on vessel with a base station setup on DEA control point #2014 (South side Wheeler Osgood waterway).
Navigation and data logging – Hypackmax Hysweep Ver 6.2A
Sound Speed - Odom Digibar

Field Procedures

Position Check
Each day after base station setup, a confidence check was made on a secondary control point DEA #2018 (Commencement Bay Marine Services) by decoupling the RTK antenna from the vessel, placing it on a fixed length staff and occupying the control point. Values agreed to within 0.1 ft for all components as displayed in the following table:

	Easting (X) US Feet	Northing (Y) US Feet	Elevation (Z) FT
Actual DEA 2018	1160508.799	706951.803	16.298
Obs. 03/05/08	1160508.90	706951.79	16.33
Obs. 03/06/08	1160508.89	706951.81	16.32

Patch Test

Prior to the start of survey operations, data was collected along a series of controlled transects to be used for checking the alignment and system latency of the survey equipment. After analysis during data processing the following correction values were determined and applied during data processing.

Roll	Pitch	Yaw	Latency
0.40°	0.20°	-0.70°	0.00 sec

Sound Velocity Casts

Detailed measurements of the sound velocity profile through the water column are crucial in multibeam surveys. Changes in the velocity profile will not only affect acoustic distance measurements, but can also cause refraction or bending of the sonar path as it passes through layers in the water column with different velocities. An ODOM Digibar Pro was used to measure the speed of sound of the water column. A total of four sound speed casts were made during survey operations. The cast showed a very homogeneous sound speed structure to the water column with average velocities of approximately 4842 ft/sec with a min – max range of 4839 to 4847 ft/sec.

Bar Check and Lead Line Comparison

A flat bar target was held below the multibeam sensor to verify draft adjustments to the system. The bar was held at a measured depth of 5.00 ft and a sampling of the raw soundings observed in the CARIS processing workstation averaged 4.95 ft. A leadline sounding taken on the eastern side of the eastern bridge footing of the 11th Street bridge of 11.38 ft, compared well to an average of 11.34 ft from 10 multibeam soundings in the same area.

Multibeam Data Acquisition

Soundings were acquired with a Reson SeaBat 8101 multibeam bathymetric sonar using a frequency of 240 kilo hertz (kHz). The system records 101 soundings in a single sonar ping. Additionally, DEA's 8101 includes options such as a stick projector for enhanced shallow water performance and the ability to output side scan sonar imagery. The stick projector option on the Reson SeaBat 8101 improves the system performance in shallow water (depths less than 150 ft).

Multibeam data was conducted by running lines both parallel and perpendicular with the waterway for the length of the project. In many areas, the survey vessel had to be "walked" along tight spaces between docks and floats to get the maximum boat coverage possible. Very few areas were inaccessible or blocked by large vessels. For this survey, the sonar head was mounted with 15° starboard angle to allow for maximum coverage of side slope areas. This enabled coverage over a range of 90° from nadir (straight down) to starboard and 60° from nadir to port with a recorded depth every 1.5°. Sonar swaths were recorded at a rate of 14 Hz as the vessel transited along the survey track lines. Multibeam data were clipped at 55° (110° total swath width) during processing to improve data quality for the main waterway, the accepted angles were opened up along the slopes and to reach under obstructions. The total swath width of full coverage mapping in a single pass varied with the water depth.

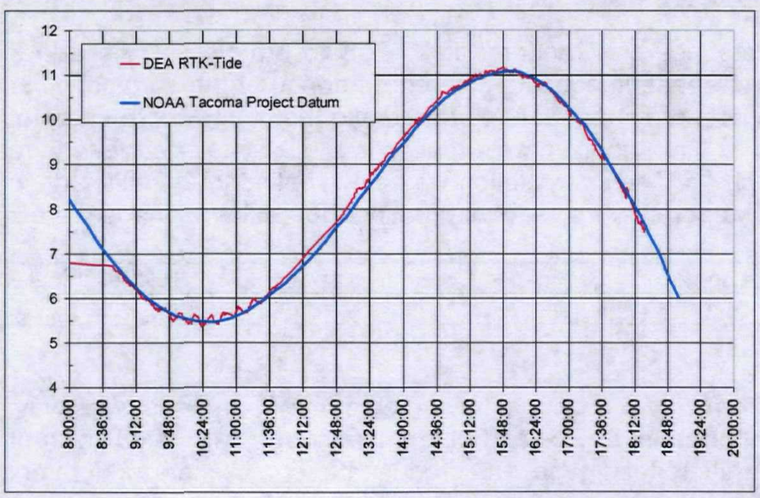
The most vital measurements in a multibeam survey are heading and roll angles. To account for vessel heading, heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor was utilized. By utilizing vessel speed over ground and heading data provided by GPS, the POS/MV can isolate horizontal accelerations from vessel turns and provide highly accurate motion data. The POS/MV system was also used to record vessel heading (yaw) from which the sonar beam orientation was derived. The POS/MV provides a higher degree of accuracy for heading measurements than a conventional gyrocompass.

The navigation and survey control system was a personal computer running Hypack MAX software. Hypack Hysweep software was used for multibeam and sensor data acquisition. Hypack MAX software allowed the swath bathymetric data to be displayed as a painted color image in a "matrix" on the navigation screen. The matrix cell size on was set to 1-ft during operations and nearly all cells were filled with sounding data. This real-time display gave the hydrographers immediate indications of data quality and coverage.

Processing Procedures

Tides

The elevation data obtained from the RTK GPS system was stripped out and averaged at a 10-second sliding window. In addition, tide data from the NOAA gauge in Tacoma (9446484) was downloaded for the survey period for comparison. These 6-minute NOAA tide values were adjusted to project datum by adding 0.80 feet. A graph showing the comparison of the two tide datasets showed close agreement. The RTK-10sec tide was used for processing the data.



Data Editing
Post-processing of multibeam data was conducted utilizing Caris HIPS multibeam analysis and processing software version 6.1/SP1/HF 7. Patch test data was analyzed and alignment corrections were applied. Water-level data was applied to adjust all depth measurements to project datum from the RTK GPS processed data. Velocity profiles were used to correct slant range measurements and compensate for any ray path bending.

Processing began with review of each survey line using Caris swath editor. Verified water surface correctors were applied to the data set at this time. Position and sensor data was reviewed and accepted. Sounding data was reviewed and edited for data flyers. Sounding data, including sonar beams reflecting from sediment in the water column or noise in the water column, were carefully reviewed before flagged as rejected. In each case, data was not eliminated and can be re-accepted in the future if required. Also during editing, real features not associated with bottom elevations but of possible interest, pilings and bridge footings, etc., were designated as examined. This designation allows these features to be included in the hillshade images which add references points to aid in interpretation. The “examined” soundings were not included in the final data exported for difference modeling or contouring.

After swath editing, all data was reviewed through the Caris HIPS subset editing program to ensure no flyers remained in the data set, or to re-accept data previously flagged in the swath editor. In the Caris subset editor, a set of lines was reviewed together for line-to-line comparison to ensure agreement to one another in a Caris session.

Data Export
To take advantage of the level of detail the multibeam bathymetric survey provided for the waterway, a 0.5-meter grid of the survey area was created by the HIPS processing software and exported to an ASCII XYZ file. This process created a 0.5-meter grid over the survey coverage area and then assigned values to each grid node with an inverse distance weighted algorithm. The ASCII XYZ points file uses the North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS), Washington South Zone with units in US Survey feet.

Data Images
The 0.5-meter database was rendered in CARIS to produce a hillshade image of the bottom bathymetry. The hillshade image is a colored rendering of the surface with shadows created by a artificial sun to help draw out features and make the image more interpretable. For the Thea-Foss waterway a 3x3 interpolation was applied to the 0.5-meter surface to reduce the distracting effects of empty pixels. The interpolation was only applied to the hillshade image and not to any other products. The paramaters used for creating the hillshade image were:

Sun Azimuth	Sun Elevation	Vertical Exaggeration
115°	45°	2X

Multibeam data from a post construction survey of the Thea Foss waterway, conducted by DEA in 2006, were imported in CARIS and difference values calculated by subtracting one surface from the other. A difference image was produced to show where bottom changes had occurred at a 6" interval. The image is predominantly gray, indicating that the bottom changed less than +/- 6". Green colors indicate areas in which the bottom is shallower than in 2006 and blue colors indicate areas where the bottom is now deeper. A new hillshade image of the 2006 data was produced using the same color and illumination parameters used for the 2008 data so that the two surveys could be directly compared.

Data Contours

The exported soundings from the 2008 multibeam survey were imported into Trimble Terramodel software for generation of 1-ft elevation contours. The contours were exported as shape files for use by ArcGIS mapping systems.

Data Files

Copies of the raw .HXS, Hypack and exported ASCII xyz data files were delivered along with this memorandum.

DAVID EVANS AND ASSOCIATES INC.

MEMORANDUM

Date: May 22, 2008
Client: Floyd | Snider
Subject: Thea Foss and Wheeler Osgood Waterways Remediation Project
Hydrographic Survey Comparison (2006 Multibeam to 2008 Multibeam)

This memorandum summarizes the comparability between two hydrographic surveys conducted within the Thea-Foss and Wheeler Osgood waterways in Tacoma, Washington. The first survey, conducted in two phases, to coordinate with construction activities, was run on December 21 & 22 of 2005 and also on February 12 of 2006. The 2008 survey was conducted on March 5 & 6 of 2008. Details of the equipment and procedures used for each survey can be found in the *Survey & Procedures* memoranda dated May 01, 2008.

Equipment
The primary equipment used between the 2006 survey and the 2008 survey was virtually identical for all the major components as shown in the following table.

Equipment	2005/2006	2008
Survey Vessel	33' - *John B Preston*	33' - *John B Preston*
Multibeam Bathymetric Sonar	Reson 8101	Reson 8101
Motion Sensor	Applanix POS/MV	Applanix POS/MV
Navigation Control	HypackMax 4.3a Gold	HypackMax 6.2a
Vessel Positioning	Trimble MS750 RTK	Trimble MS750 RTK
Sound Velocity	Odom Digibar	Odom Digibar

Although, the same RTK GPS equipment was used on both surveys, different base station and control check stations had to be used because the earlier control points (DEA #2016 & #2019) had been destroyed by construction activity. The 2008 base station was setup on other points from the original project control network and position checks verified the points were undisturbed. Therefore, from a positioning standpoint, the 2006 and 2008 are very comparable.

Survey Coverage and Line Orientation

When the 2005/2006 multibeam survey was conducted, there was still construction activity going on in parts of the area and certain areas were difficult to access so data coverage along some areas was limited. To gain coverage in and under objects during the 2006 survey, especially along the western edge of the Thea Foss waterway outer beam data was used which may be of a slightly lower accuracy due to the low grazing angles associated with these beams. During the 2008 survey a significant effort was made to try to achieve complete multibeam coverage in all areas. A few small areas which were blocked by vessels or which the survey vessel could not image in to, lack coverage, but for the majority of the area the 2008 coverage is complete. In general, the trackline orientation of the multibeam surveys is controlled by the shape of the waterway and the location of the various docks and structures which constrain vessel navigation and, by default, produced similar trackline orientations between the 2006 and 2008 surveys. The need for duplicating survey transects is not nearly as necessary in multibeam surveys as it is in single beam surveys where data is only obtained directly below the survey vessel.

Quality Control & Checks

The survey conducted in 2006 and 2008 followed similar quality control procedures which are summarized in the aforementioned *Survey & Procedure* memos of May 01, 2008. These quality control procedures included:

- Position checks on project control points
- Sound velocity casts
- Comparison of RTK tide data to observed NOAA tides
- Bar checks to confirm sonar draft settings
- Lead Line soundings

Feature Matching

For additional quality assurances of the 2006 and 2008 multibeam surveys, data was acquired over a very distinct feature located in the central portion of the Thea-Foss waterway. A remnant of a bridge footing provided a fixed, sharp feature which allowed comparisons to be made of vertical and horizontal repeatability of the surveys. A hill shade image shows the structure and the position of the lines along which the profiles were taken. The profiles are depicted with a 2X vertical exaggeration on a one foot vertical and 20 foot horizontal grid. Elevation values, color coded to match their respective surveys, are displayed at each 20-foot grid interval. In general the profiles show very good repeatability of the two surveys.

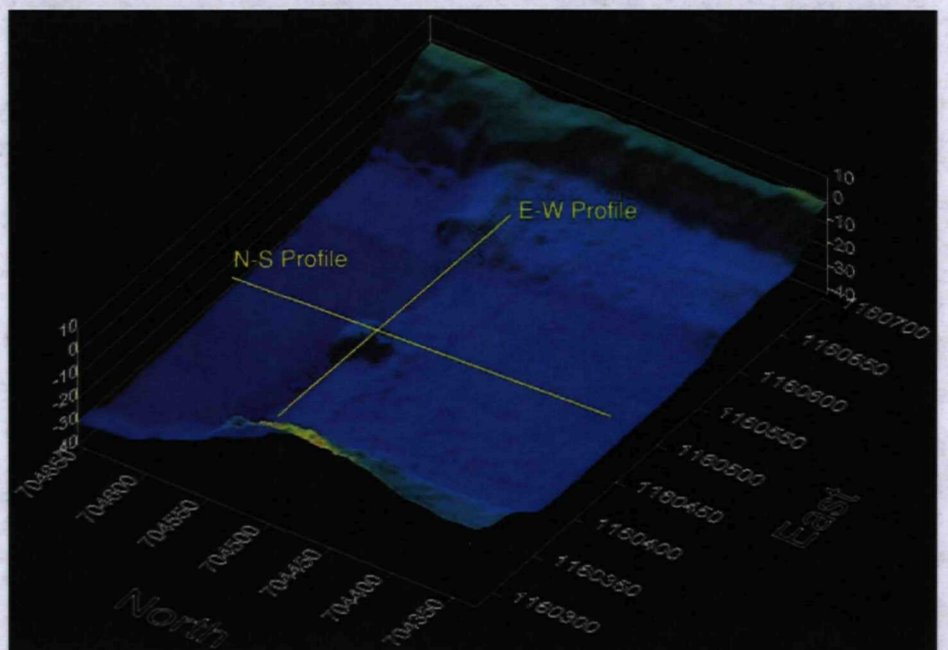


Figure 1 Hill shade image of relict bridge footing viewed from the SW. VE = 2X

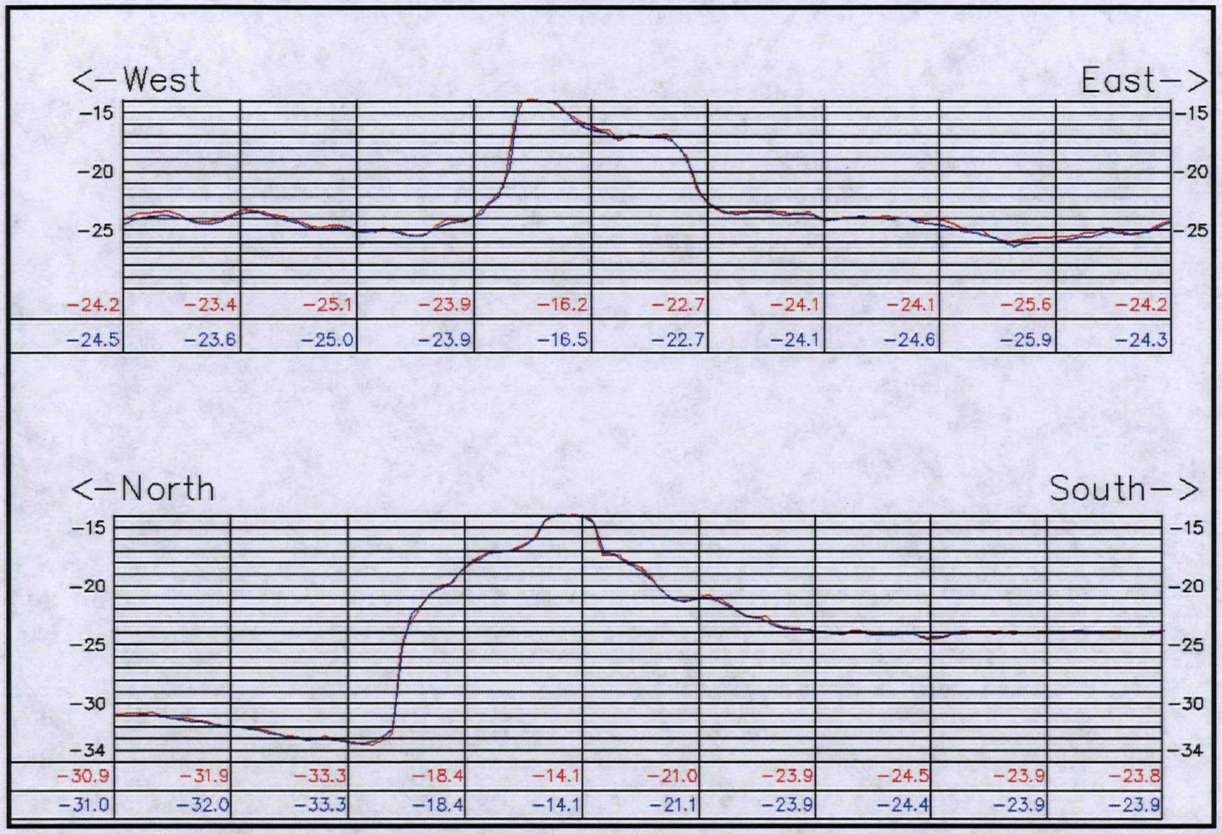


Figure 2 Profile comparing 2006 (red) and 2008 (blue) multibeam surfaces. VE = 2X.

Summary of survey comparability

In general, the systems and procedures used to conduct the multibeam surveys in 2006 and 2008 produced very good repeatability. The areas showing the largest systematic differences appeared on the extreme edges of the data on the West side of the Thea Foss waterway. It is believed that the differences seen in these areas are possibly attributable to using outer swath beams used in order to extend coverage of the 2006 survey which was limited by obstructions. The 2008 survey covered this area more completely, used more inner beam data and tied very well to upland elevations surveyed in by a land crew in April of 2006. The quality and coverage of the 2008 survey should serve as an excellent baseline surface for future bathymetric comparisons.

ATTACHMENT B

YEAR 4 (2010) SURVEY EQUIPMENT AND PROCEDURES

DAVID EVANS AND ASSOCIATES INC.

MEMORANDUM

Date: May 06, 2010
Client: Floyd | Snider
Subject: Thea Foss and Wheeler Osgood Waterways Remediation Project
Year 4 (2010) Subtidal Cap Monitoring Hydrographic Survey
Summary of Survey Procedures and Equipment

Project Parameters

Horizontal Datum: *NAD 83/91*
Vertical Datum: *Project Datum (Tidal 22 = 20.0')*
Coordinate System: *Washington State Plane – South Zone*
Units: *US Survey Feet*

Survey Dates

March 1 - 3, 2010

Survey Crew

Greg Baird – Senior Hydrographer, ACSM* Hydrographer, OR PLS
Travis Brennan – Hydrographer III
Nicholas Lesnikowski – Lead Hydrographer, Project Manager, ACSM* Hydrographer
Client representatives Jessi Massingale and Megan McCullough were on board through significant portions of survey operations.

Equipment

Vessel – DEA's 33-foot *John B Preston*
Multibeam – Reson 8101 240 kHz, 101 beam, 150° swath with 15° roll bias to starboard.
Motion Sensor – Applanix POS-MV
Heading Sensor – Applanix POS-MV
Positioning – Trimble MS750 RTK GPS rover on vessel with a base station setup on DEA control point #2011* (North side of Johnny's Dock Restaurant)
Navigation and data logging – Hypackmax Hysweep ver. 2009a
Sound Speed - AML SV Plus

** see note regarding Control Point 2011*

Survey Control and Adjustment

The project survey control point # 2014 used in the previous surveys for the RTK-GPS station was found to be destroyed. For this survey the existing project survey control point #2011 was selected for the RTK-GPS base station. The selection of #2011 was based on its location for accessibility and specifically the lack of obstructions inhibiting GPS signal.

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The RTK-GPS base station occupied existing project survey control point #2011 for the multibeam survey conducted on March 1 – 3, 2010 and based on repeated RTK-GPS observations of three other existing project survey control monuments (2000, 2018 and 3000) and static GPS observations of control points 2018 and 3000, it was determined that survey control monument #2011 was out of position from the published coordinates and elevation. The analysis of the GPS observations resulted in applying a shift of 0.293 feet in northing, -0.492 feet in easting and -0.212 feet in elevation with a standard deviation of 0.028 feet in northing, 0.038 feet in easting and 0.004 feet in elevation. The reason for the survey control point #2011 being out of position may be due to the apparent recent construction of the surrounding parking lot and an apparently new concrete seawall located near the control point.

Field Procedures

Position Check

Each day after base station setup, a confidence check was made on a secondary control point DEA #2018 (Commencement Bay Marine Services) by decoupling the RTK antenna from the vessel, placing it on a fixed length staff and occupying the control point. These procedures alerted the survey crew to a slight discrepancy which was later attributed to the base station control point being displaced from its published coordinate values. Additional survey procedures and checks were made on points 2012, 2000 and 3000 during operations to insure a valid adjustment to the data could be accomplished in post processing.

After applying the resulting coordinate and elevation shift, the position check values on the historical project control check-in monument # 2018 were better than 0.1 ft in all dimensions as shown in the table below.

UTC TIME	*DATE*	*EAST (US ft)*	*NORTH (US ft)*	*ELEV. (US ft)*	
		1160508.90	**706951.80**	**16.30**	**Published Value 2018**
23:14	3/1/2010	1160508.86	706951.78	16.30	Adj. Pos. Check
		-0.03	**-0.02**	**0.00**	**Error of Closure**
17:05	3/2/2010	1160508.82	706951.75	16.28	Adj. Pos. Check
		-0.08	**-0.05**	**-0.02**	**Error of Closure**
21:44	3/2/2010	1160508.82	706951.80	16.30	Adj. Pos. Check
		-0.08	**0.00**	**0.00**	**Error of Closure**
15:15	3/3/2010	1160508.86	706951.78	16.28	Adj. Pos. Check
		-0.04	**-0.02**	**-0.02**	**Error of Closure**
19:25	3/3/2010	1160508.83	706951.80	16.28	Adj. Pos. Check
		-0.07	**-0.01**	**-0.02**	**Error of Closure**

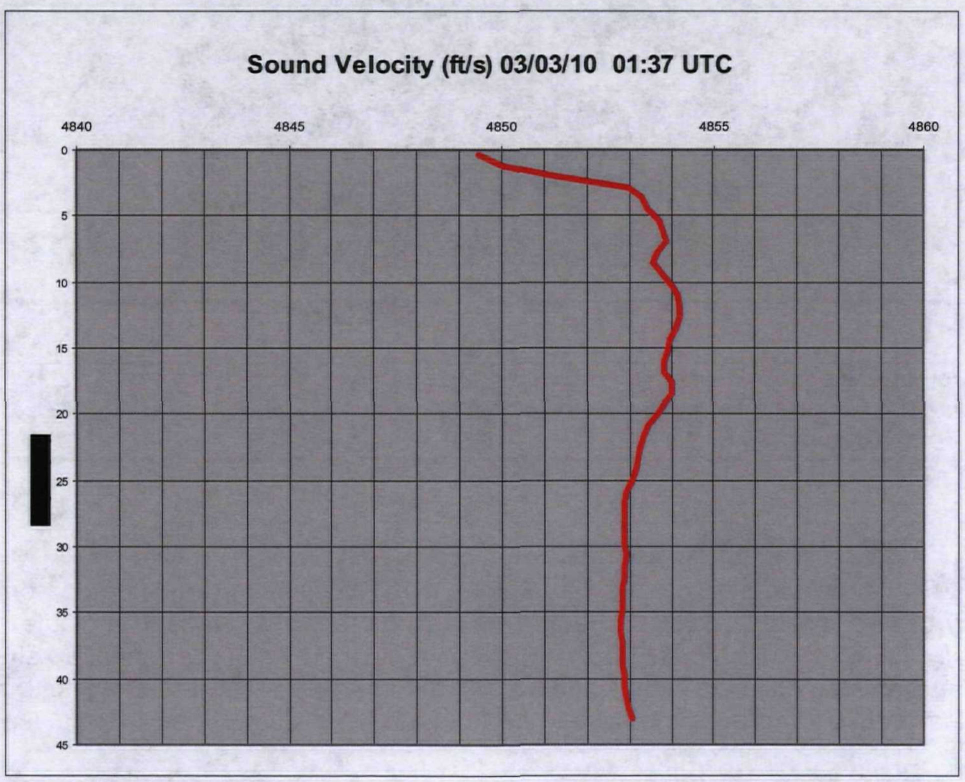
Patch Test

Prior to the start of survey operations, data was collected along a series of controlled transects to be used for checking the alignment and system latency of the survey equipment. After analysis during data processing the following correction values were determined and applied during data processing.

Roll	Pitch	Yaw	Latency
0.52°	1.04°	0.55°	0.00 sec

Sound Velocity Casts

Detailed measurements of the sound velocity profile through the water column are crucial in multibeam surveys. Changes in the velocity profile will not only affect acoustic distance measurements, but can also cause refraction or bending of the sonar path as it passes through layers in the water column with different velocities. An AML SVPlus was used to measure the speed of sound of the water column. A total of 13 sound speed casts were made during survey operations. The cast showed a very homogeneous sound speed structure to the water column with average velocities of approximately 4852 ft/sec throughout the area. A typical sound velocity cast is shown in the graph below.



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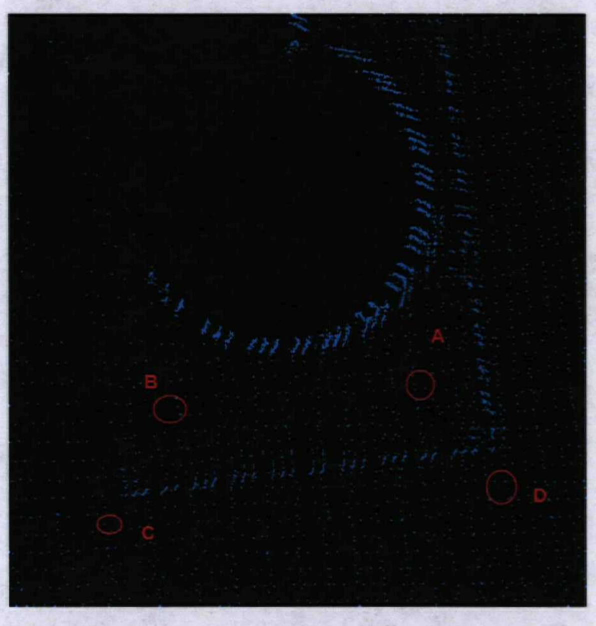
Bar Check and Lead Line Comparison

A flat bar target was held below the multibeam sensor to verify draft adjustments to the system. The bar was held at a measured depth of 2 meters (6.56 ft) and 4 meters (13.12 ft) directly below the sonar transducer head and data recorded. The data was processed in the CARIS processing workstation and a sampling of raw soundings at each depth averaged 2.01 m and 4.01 m respectively. The average difference observed was 0.01 m (0.03 ft).

A series of four lead-line soundings, taken on the south side of the eastern bridge footing of the 11th Street bridge, compared well to multibeam soundings in the same area as shown in the figure below.



	Lead Line Location			
	A	B	C	D
Tide Corr Leadline (ft)	11.24	11.22	23.51	22.95
Tide Corr Multibeam (ft)	11.25	11.29	23.69	23.06
Difference (ft)	**0.01**	**0.06**	**0.17**	**0.11**

Multibeam Data Acquisition

Soundings were acquired with a Reson SeaBat 8101 multibeam bathymetric sonar using a frequency of 240 kiloHertz (kHz). The system records 101 soundings in a single sonar ping. Additionally, DEA's 8101 includes options such as a stick projector for enhanced shallow water performance and the ability to output side scan sonar imagery. The stick projector option on the Reson SeaBat 8101 improves the system performance in shallow water (depths less than 150 ft).

Multibeam data acquisition was conducted by running lines both parallel and perpendicular with the waterway for the length of the project. In many areas, the survey vessel had to be "walked" along tight spaces between docks and floats to get the maximum bottom coverage possible. Very few areas were inaccessible or blocked by large vessels. For this survey, the sonar head was mounted with 15° starboard angle to allow for maximum coverage of side slope areas. This enabled coverage over a range of 90° from nadir (straight down) to starboard and 60° from nadir to port with a recorded depth every 1.5°. Sonar swaths were recorded at a rate of 14 Hz as the vessel transited along the survey track lines. Multibeam data were clipped at 55° (110° total swath width) during processing to improve data quality for the main waterway; the accepted angles were opened up along the slopes and to reach under obstructions. The total swath width of full coverage mapping in a single pass varied with the water depth.

The most vital measurements in a multibeam survey are heading and roll angles. To account for vessel heading, heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor was utilized. By utilizing vessel speed over ground and heading data provided by GPS, the POS/MV can isolate horizontal accelerations from vessel turns and provide highly accurate motion data. The POS/MV system was also used to record vessel heading (yaw) from which the sonar beam orientation was derived. The POS/MV provides a higher degree of accuracy for heading measurements than a conventional gyrocompass.

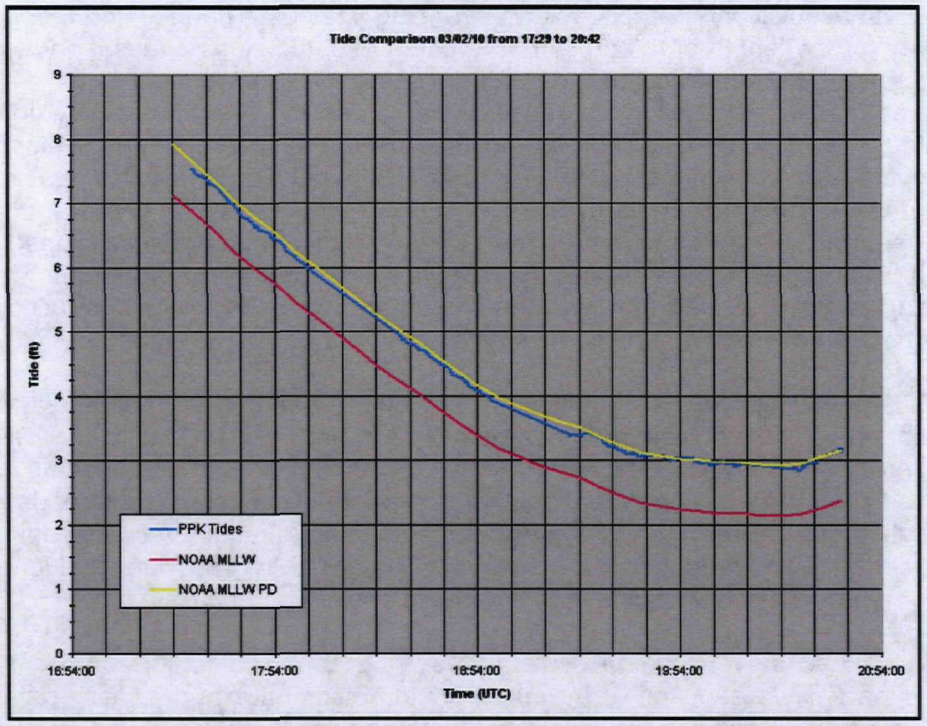
The navigation and survey control system was a personal computer running Hypack MAX software. Hypack Hysweep software was used for multibeam and sensor data acquisition. Hypack MAX software allowed the swath bathymetric data to be displayed as a painted color image in a "matrix" on the navigation screen. The matrix cell size on was set to 1-ft during operations and nearly all cells were filled with sounding data. This real-time display gave the hydrographers immediate indications of data quality and coverage.

Processing Procedures

Tides

The elevation data obtained from the RTK GPS system was written to the .xtf files which were then converted to CARIS .hdcs format. Post processed (PPK) attitude, navigation and error data are applied to the Caris formatted files. The tide data was corrected to project datum using a single value of -23.55 meters (-77.25 feet) which adjusts the GPS GRS80 ellipsoidal heights to project vertical datum. The data is then reviewed for spikes or outages.

In addition, tide data from the NOAA gauge in Tacoma (9446484) was downloaded for the survey period for comparison. These 6-minute NOAA tide values were adjusted to project datum by adding 0.80 feet. A graph showing the comparison of the two tide datasets showed close agreement. The PPK tide was used for processing the data.



Data Editing

Post-processing of multibeam data was conducted utilizing Caris HIPS multibeam analysis and processing software version 6.1/SP1/HF7. Patch test data was analyzed and alignment corrections were applied. Water-level data was applied to adjust all depth measurements to project datum from the PPK GPS processed data. Velocity profiles were used to correct slant range measurements and compensate for any ray path bending.

Processing began with review of each survey line using Caris swath editor. Verified water surface correctors were applied to the data set at this time. Position and sensor data was reviewed and accepted. Sounding data was reviewed and edited for data flyers. Sounding data, including sonar beams reflecting from sediment in the water column or noise in the water column, were carefully reviewed before flagged as rejected. In each case, data was not eliminated and can be re-accepted in the future if required.

After swath editing, all data was reviewed through the Caris HIPS subset editing program to ensure no flyers remained in the data set, or to re-accept data previously flagged in the swath editor. In the Caris subset editor, a set of lines was reviewed together for line-to-line comparison to ensure agreement to one another in a Caris session.

Data Export

To take advantage of the level of detail the multibeam bathymetric survey provided for the waterway, a 0.5-meter grid of the survey area was created by the HIPS processing software and exported to an ASCII XYZ file. This process created a 0.5-meter grid over the survey coverage area and then assigned values to each grid node with an inverse distance weighted algorithm. The ASCII XYZ points file uses the North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS), Washington South Zone with units in US Survey feet.

Data Images

The 0.5-meter database was rendered in CARIS to produce a hillshade image of the bottom bathymetry. The hillshade image is a colored rendering of the surface with shadows created by a artificial sun to help draw out features and make the image more interpretable. For the Thea-Foss waterway a 3x3 interpolation was applied to the 0.5-meter surface to reduce the distracting effects of empty pixels. The interpolation was only applied to the hillshade image and not to any other products. The paramaters used for creating the hillshade image were:

Sun Azimuth	Sun Elevation	Vertical Exaggeration
115°	45°	2X

Multibeam data from a post construction survey of the Thea Foss waterway (baseline) and the Year-2 monitoring survey, conducted by DEA in 2006 and 2008 respectively, were imported in CARIS and difference values calculated by subtracting each of these surfaces from the current Year-4 surface model. A difference image was produced to show where bottom changes had occurred at a 6" interval. The image is predominantly gray, indicating that the bottom changed less than +/- 6". Green colors indicate areas in which the bottom is shallower than previous and blue colors indicate areas where the bottom is now deeper. A new hillshade image of the 2010 data was produced using the same color and illumination parameters used for prior deliverables so all surveys could be directly compared.

The Year-2 processing included the production of profile data to compare bottom conditions in areas which only had single beam data coverage. Profiles were made using Year-4 data along the same profile sections and added to the previous cross-section display for bottom change evaluation.

Data Contours

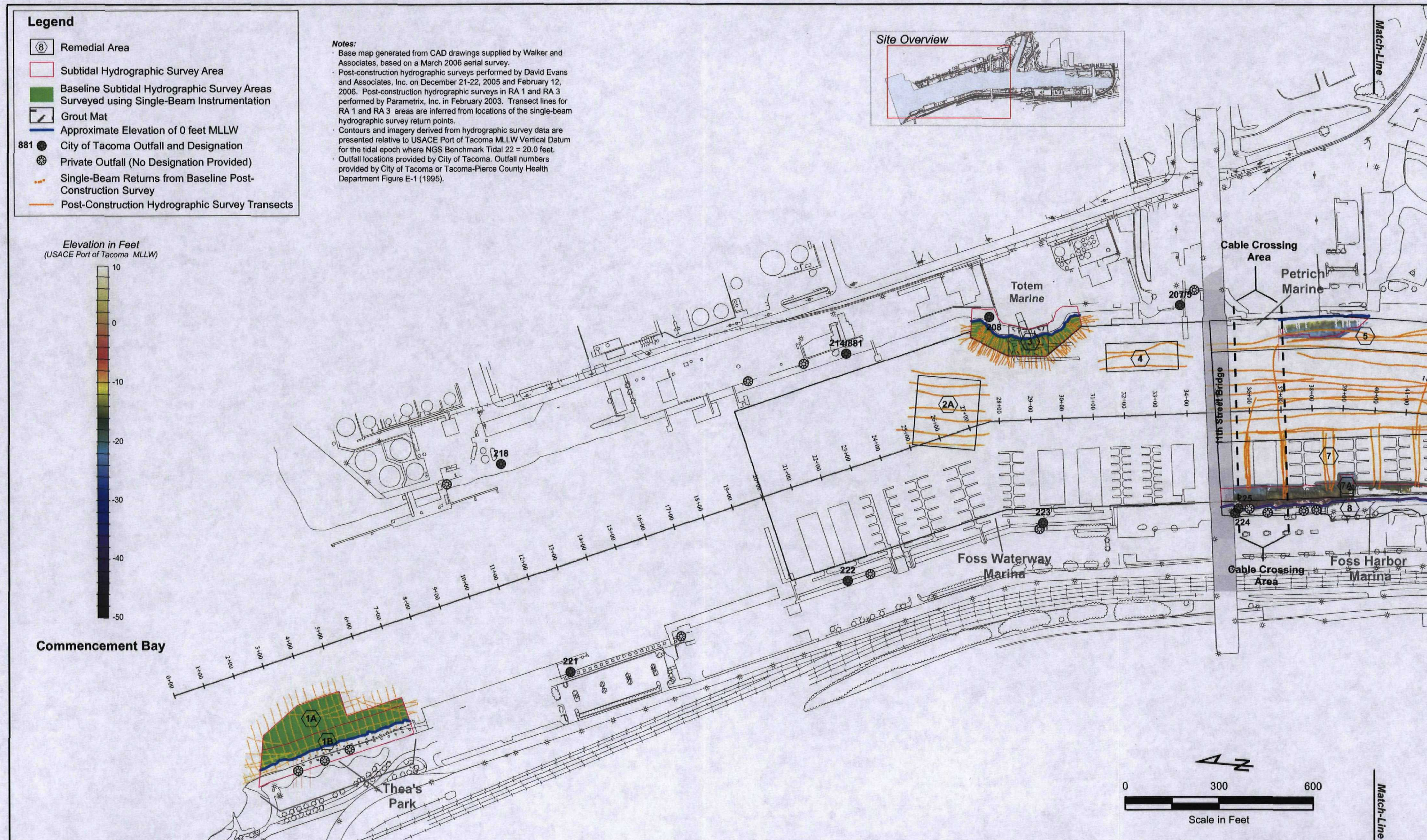
The exported soundings from the 2010 multibeam survey were imported into Trimble Terramodel software for generation of 1-ft elevation contours. The contours were exported as shape files for use by ArcGIS mapping systems. A hardcopy set of contours stamped by a licensed Washington Professional Land Surveyor (PLS), was also produced.

Data Files

Copies of the raw .HXS, Hypack and exported ASCII xyz data files were delivered along with this memorandum.

ATTACHMENT C

BASELINE, YEAR 2 AND YEAR 4 SURVEY TRANSECT LINES



FLOYD | SNIDER strategy • science • engineering	**Thea Foss and Wheeler-Osgood Waterways** **OMMP**	**Figure C-1 (Page 1 of 2)** **Overview of Baseline** **Hydrographic Survey Transect Lines**

File: F:\projects\COT-Oncall\GIS\2008 Hydrographic PFM\MXD\Report Figures\Figure C-1 (Overview of Baseline Hydrographic Survey Areas with Transect Lines (1of2)).mxd
6/3/2008 12:09 PM

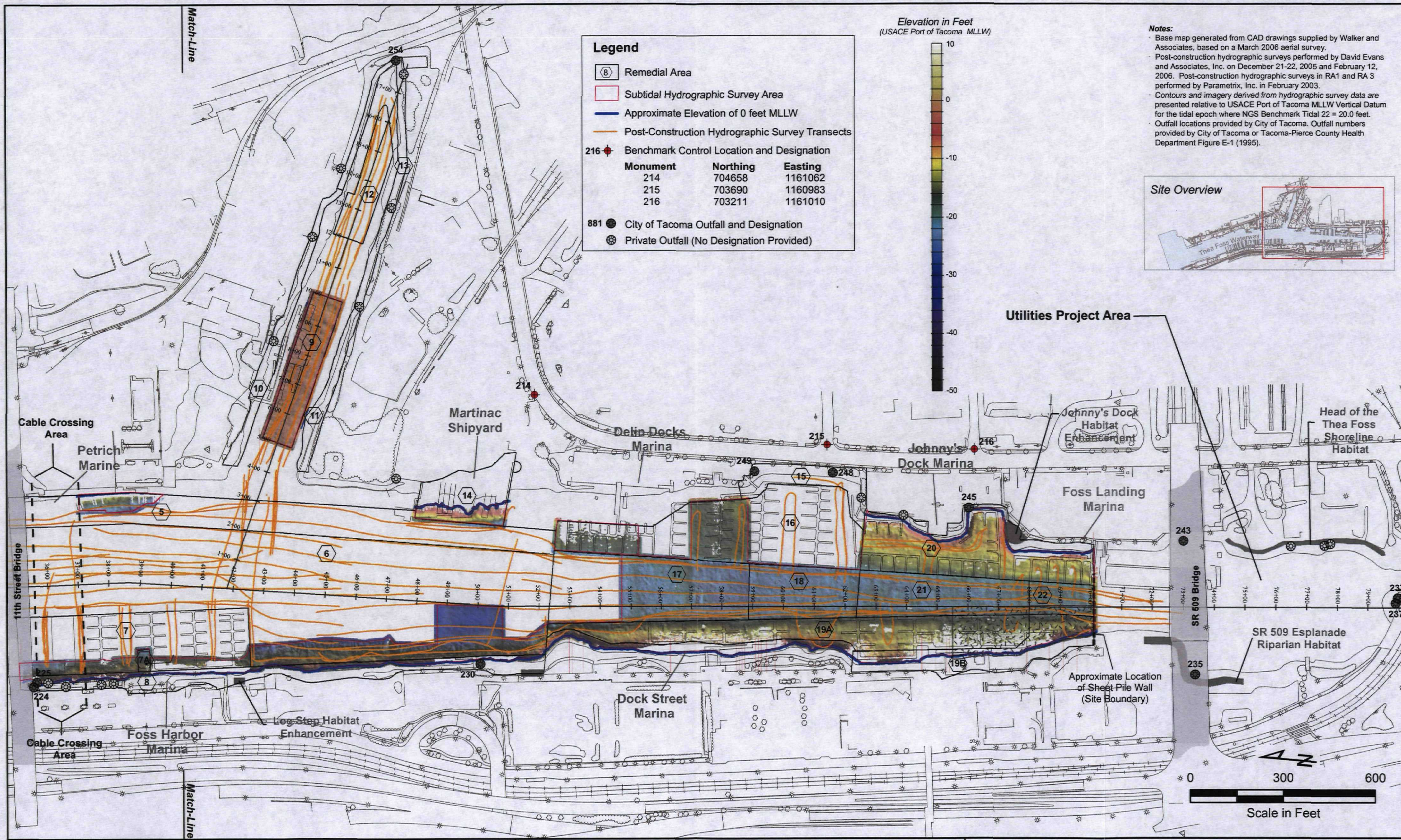


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Figure C-1 (Page 2 of 2)
Overview of Baseline Hydrographic Survey Transect Lines

File: F:\projects\COT-Oncall\GIS\2008 Hydrographic PFM\MXD\Report Figures\Figure C-1 (Overview of Baseline Hydrographic Survey Areas with Transect Lines (2of2)).mxd
6/3/2008 12:06 PM

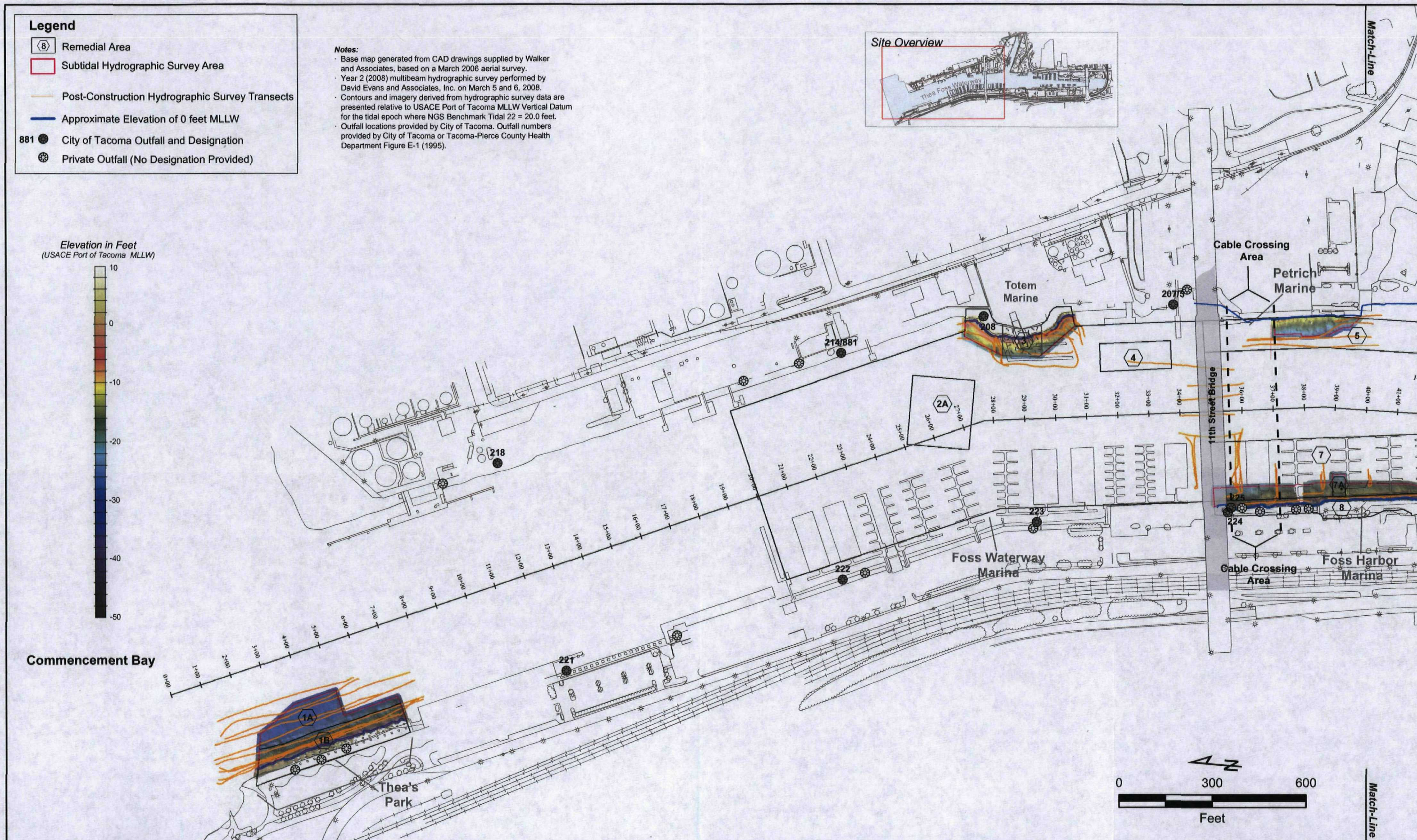

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**Figure C-2 (Page 1 of 2)
Overview of Year 2 (2008)
Hydrographic Survey Transect Lines**

File: F:\projects\COT-Oncall\GIS\2008 Hydrographic PFM\MXD\Report Figures\Figure C-2 (Overview of Year 2 (2008) Hydrographic Survey Areas with Transect Lines (1of2)).mxd
6/3/2008 12:11 PM

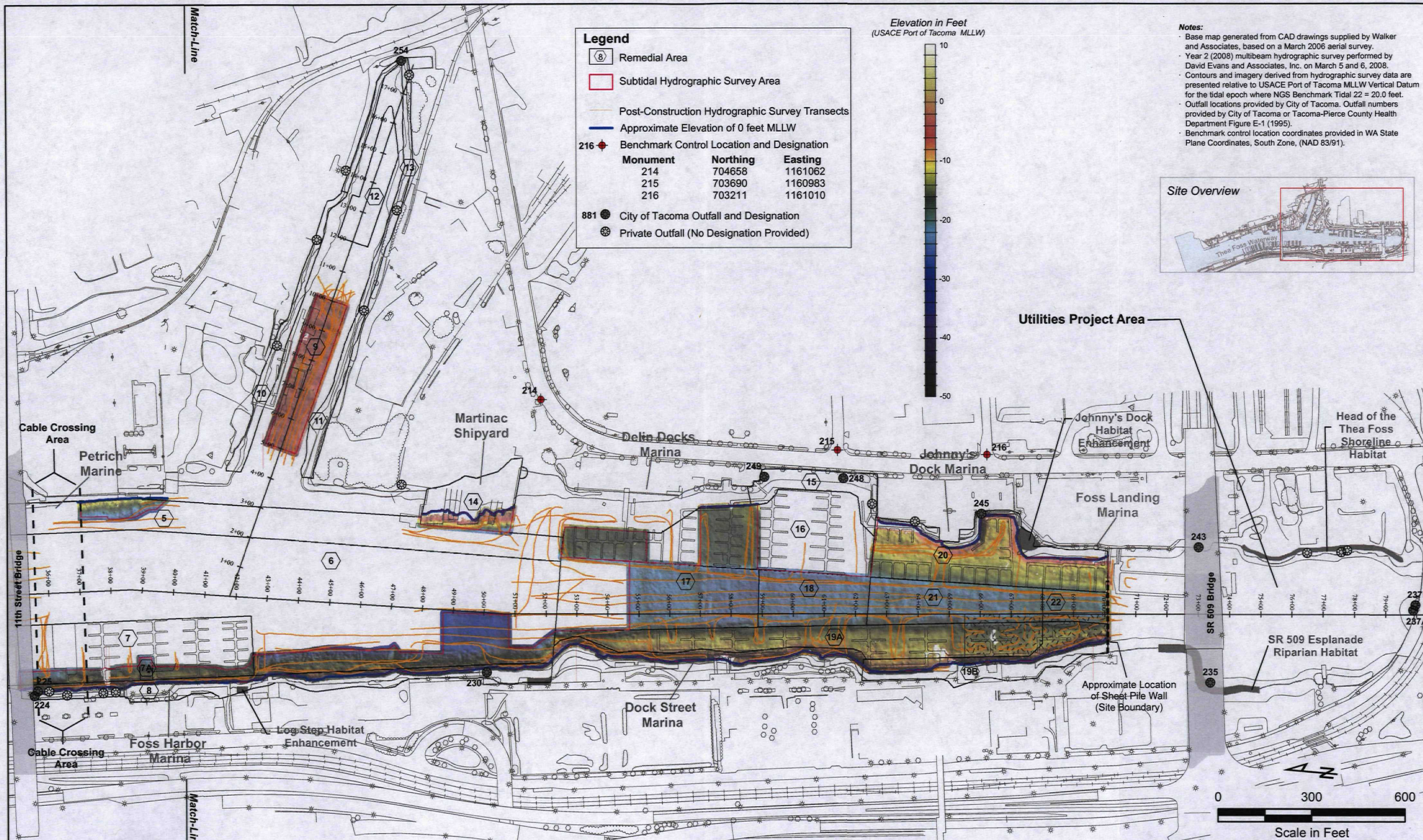

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Figure C-2 (Page 2 of 2)
Overview of Year 2 (2008)
Hydrographic Survey Transects

File: F:\projects\COT-Oncall\GIS\2008 Hydrographic PFM\MXD\Report Figures\Figure C-2 (Overview of Year 2 (2008) Hydrographic Survey Areas with Transect Lines (2of2)).mxd
6/3/2008 12:13 PM

Legend

(8)	Remedial Area
red box	Subtidal Hydrographic Survey Area
	Grout Mat
blue line	Approximate Elevation of 0 feet MLLW
orange line	Post-construction Hydrographic Survey Transects
881 ●	City of Tacoma Outfall and Designation
⊛	Private Outfall (No Designation Provided)
2018 ✦	Benchmark Control Location and Designation

Monument	Northing	Easting
2000	709,236	1,158,829
2018	706,952	1,160,509
3000	708,339	1,159,088

Notes:

- Base map generated from CAD drawings supplied by Walker and Associates, based on a March 2006 aerial survey.
- Post-construction hydrographic surveys performed by David Evans and Associates, Inc. in March 2010.
- Imagery derived from hydrographic survey data is presented relative to USACE Port of Tacoma MLLW Vertical Datum for the tidal epoch where NGS Benchmark Tidal 22 = 20.0 feet.
- Outfall locations provided by City of Tacoma. Outfall numbers provided by City of Tacoma or Tacoma-Pierce County Health Department Figure E-1 (1995).

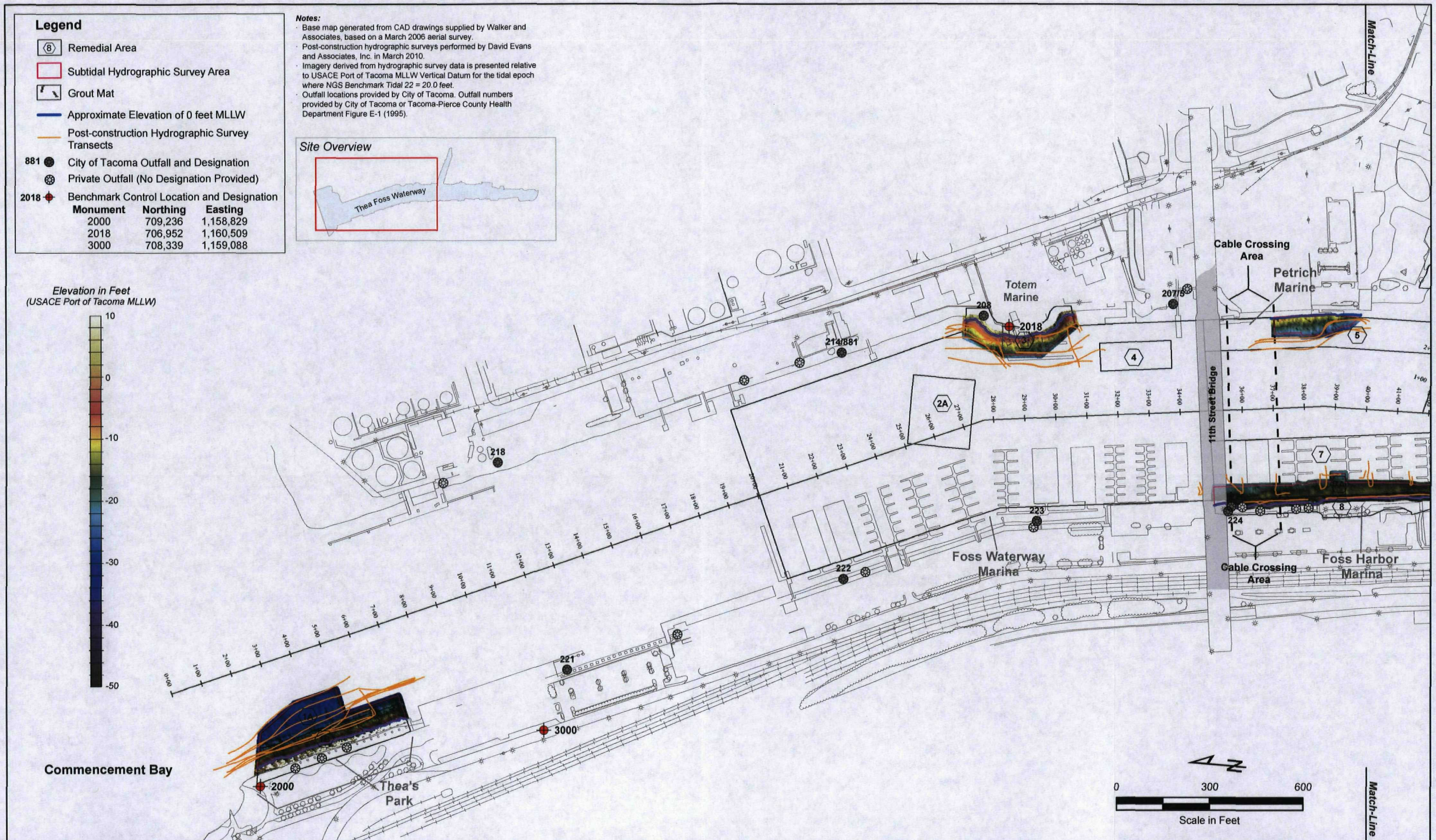

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Figure C-3 (Page 1 of 2)
Overview of Year 4 (2010)
Hydrographic Survey Transect Lines

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure C-3 (Overview of Year 4 (2010) Hydrographic Survey Areas with Transect Lines (1of2)).mxd
Date: 5/13/2010

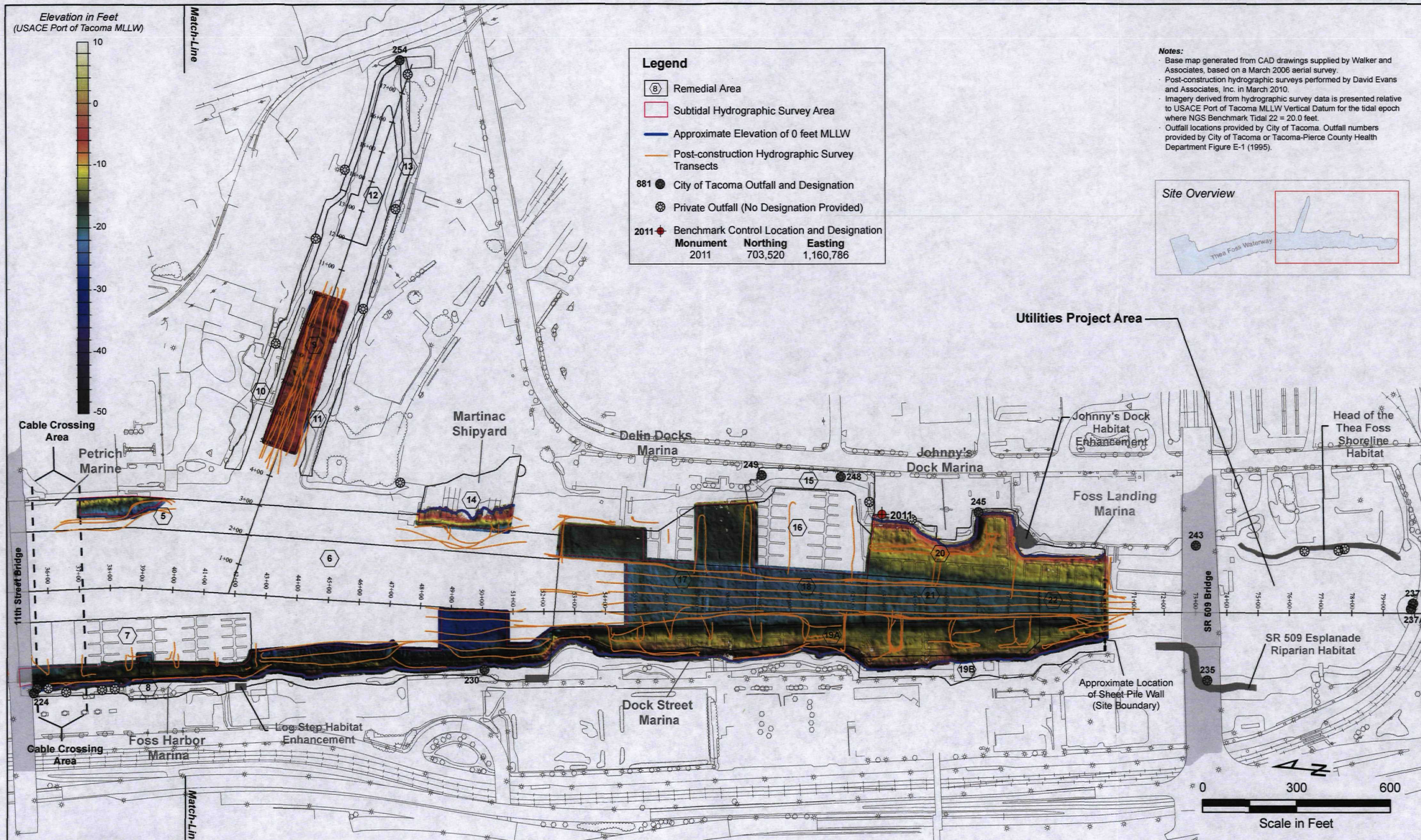

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Figure C-3 (Page 2 of 2)
Overview of Year 4 (2010)
Hydrographic Survey Transect Lines

File: F:\projects\COT-Oncall\GIS\2010 Hydrographic PFM\MXD\Figure C-3 (Overview of Year 4 (2010) Hydrographic Survey Areas with Transect Lines (2of2)).mxd
Date: 5/13/2010